1.6.3 Facilities and Rolling Stock

(1) Track and structure

1) Track addition

Railway capacity depends on various factors such as train speed, difference in speeds of individual trains, distance between stations, track layout at station yards, train stoppage time, signal block systems, etc. When railway capacity reaches its upper limit, possible measures to intensify transport capacity may be: increase of the number of cars of which a train is made up, addition of refuge tracks and crossing loops, addition of main tracks, improvement of the signalling system, modernization of motive power, etc. As measures to intensify transport capacity available in the Bangkok area, both electrification and introduction of electric railcars may be expected. A steep rise in transport capacity may be expected through track addition and improvement of block signals.

Since the areas up to 50 km from Hua Lamphong are considered to be within a commuting area, in order to improve train frequency and train speed, it is necessary to ensure at least double track lines. Farther than the commuting area, track addition should be realized ascertaining future demand. According to the plan of Hopewell and the SRT, necessary track addition for the time being will be mostly satisfied. Although no specific schedule has been decided by the SRT for the Maeklong Line, at least double track lines may be necessary for the section from Pho Nimit (the terminal of the Hopewell Project) to Maha Chai.

Land required for track addition has already been acquired. However, extra time and money may be required in order to evict squatters or to get back leased land. Therefore, it will be important not only to intensify daily land management but also to take necessary measures to exclude occupancy by others. The latter should be made beforehand in order to avoid any possible social matters such as residential problems and removal of small-scaled shops.

At present, track addition has been decided for the following sections to be realized by the year 2000.

Khlong Rangsit - LopBuri	104km
Hua Mak - Chachoengsao	45km
Bang Sue - Nakhon Pathom	41km

Ban Phachi - Map Kabao 44km

Hopewell Project plans track addtion for the following sections by the year 2000.

Yommarat - Khlong Rangsit
Yommarat - Hua Mak
Wong Wien Yai - Pho Nimit
Thon Buri - Taling Chan
Yommarat - Thon Buri (double track new line)
Hua Lamphong - Wong Wien Yai (double track new line)

2) Improvement of station track layout

The objectives of station tracks are to have the best functions for suitably conducting the operation of trains for required transport. It is necessary to plan station track layout by taking into consideration safety, speed, efficiency and costs.

There are various kinds of trains such as rapid trains and local trains for commuter service, express trains, special express trains and low-speed freight trains. These trains have their own objectives. It is, therefore, necessary to efficiently operate trains with different kinds of speed. Facilities used for transfer from high-speed trains to low-speed trains should be prepared for the convenience of passengers. Facilities required for passing-by and overtaking should be provided at suitable stations by coordinating with train operation plans.

As for high efficiency, it is necessary to plan station tracks suitable for conducting parallel work and preventing conflict with the shunting of trains. As for the long-term view, it is important to make track layout allowing room for future facilities if these facilities are expected to be expanded.

Track layout of stations is much concerned with the carrying capacity of a line. A single track line should not lack suitable crossing loops. Even in a double track line, refuge tracks are necessary for low speed trains like freight trains or ordinary passenger trains to give a way to high speed trains at every suitable spot. If not, the carrying capacity of the line is restricted by low speed trains.

3) Structure and roadbed

For track addition, low banking will be constructed for general sections. However, since soft ground is found in many places, measures against soft ground should be incorporated in the construction work. At any rate, soil of high quality must be conveyed from mountainous areas. For bridge construction from the viewpoint of taking measures against noise and reducing maintenance expenses, either PC or RC bridges are recommended.

4) Track

Caused by the speed up of trains, track destruction energy increases in proportion to a square of the speed. Moreover, once a failure such as rail breakage occurs, damage resulting from such a failure will be greatly enlarged.

As an example of track structure classification, adopted in Japan, which is in accordance with maximum speed and total passing tonnage, is shown in Table 1.6.3.

Table 1.6.3 Track Classification

Item \ Class	1st class	2nd class	3rd class	4th class
Passing tonnage	20 million t or more	10-20 million t	5-10 million t	5 million t or less
Maximum train speed	120 km/h	120 km/h	110 km/h	85 km/h
Kind of rail	60 kg/m rail	60 kg/m or 50 km/m rail	50 kg/m rail or heavier	50 kg/m rail or heavier
Kind of sleeper	PC sleepers, 44pcs/25m or more	PC sleepers, 39pcs/25m or more	PC or wooden sleepers 39pcs/25m	PC or wooden sleepers 37pcs/25m
Ballast depth	Crushed stone, 250mm or more	Crushed stone, 250mm or more	Crushed stone, 200mm or more	Crushed stone 200mm or more

In consideration of increased speed and frequency of trains, reinforced tracks are required for commuter sections. In such section 50 kg/m (at least) long rails, PC sleepers and ballast 25 cm thick are necessary. Crossings (of turnouts) should be of manganese steel. For long bridges, employment of slab tracks and directly connected tracks should be considered as a problem for the future. (Also, for main line sections which play an important role in transport within urban districts, it will be necessary to install reinforced tracks of the same quality as mentioned above, replacing with the existings tracks one by one.)

5) Grade separation

In order to ensure safety of trains and to avoid overcrowding at at-grade crossings of a railway and a road, grade separation is desirable for major roads.

In urban areas where there are a lot of crossings, it would lower total construction costs to have a continuous railway overpass rather than to make individual road flyovers, and it would be more convenient for road users. However, in the suburbs where the distance between roads is larger, as the gradient limit for roads is several times as large as that for railways, it would be less expensive to make road flyovers/underpasses. The effect of grade separation was shown in the former JICA Study, "The Feasibility Study on Track Elevation Project of Existing Railway Lines in the Bangkok Metropolitan Area, 1984".

In the Hopewell project, railway viaducts will be extended to Khlong Rangsit on the Northern line, Hua Mak on the Eastern line, Taling Chan on the Southern line and Pho Nimit on the Maeklong line. It is desirable to keep tracks elevated after passing the road crossings adjacent to those stations. Beyond the Hopewell project section, all the multi-lane roads within the commuter section should be provided with grade separations. Beyond the commuter section, a program for building grade separations one after another at crossings with main roads should be carried forward. There are 3 possible methods for grade separation ; road flyovers, road underpasses and track elevation. It is necessary to discuss with the road administrator how to make grade separation including a matter of cost sharing.

On the Northern Line, it is necessary to keep the track elevated to the road crossing at 29km751m just passed Khlong Rangsit station. On the Eastern Line, Srinak Harin Road beyond Hua Mak station should be passed by elevated track. On the Southern Line between Ton Samrong to Nakhon Pathom, if it is difficult to combine some roads with others, track elevation will be necessary in the future. On the Maeklong line, track should be kept elevated to Wutthakat Rd. and Ekachai Rd. As for the two road crossings near Maha Chai, it may need track elevation to cross over the river. Therefore, the grade separation work for the road crossings will be postponed.

6) Station

(a) Necessary functions of a station

In order to function as stations to deal with commuters, the past image of of the SRT stations must move ahead considerably by leaps and bounds.

For the convenience of long-distance passengers, stations are required to offer:

- Sufficient guidance and information, because passengers are not accustomed to using the stations
- Sufficient time and space for their movements, and getting on trains, because they carry a lot of baggage

On the other hand, in the case of commuters:

- Passengers are accustomed to using the stations. Moreover, they are able to move quickly with no guidance.
- They come to the stations at certain times for the trains they are used to taking. Moreover, since trains arrive and depart frequently during such commuter rush hours, no large space is required for them to wait for their trains.

At present, SRT stations are mainly prepared for long-distance travelers. However, facilities in waiting rooms, etc. are insufficient.

For the Bangkok area where the main purpose of stations may shift to commuters, in order to ensure smooth handling of a large number of passengers a suitable layout of facilities based on full consideration of passenger flow will be necessary.

In order to ensure smooth handling of a large number of commuters, ticket examination in the trains enforced this far will not be a suitable means to fully collect fares. Therefore, it will be necessary to arrange latches letting passengers go through one or two gateways to check tickets. In addition, introduction of a commuter pass is recommended in order to simplify the job of ticket selling and to get passengers accustomed to using trains. A further attempt to introduce a system, which is established in Japan, that makes employers bear the cost of commuting passes for their employees as a necessary business measures would be significant.

Fig. 1.6.5 shows a typical operation pattern related to a station plan. Fig. 1.6.6 shows a typical station track layout pattern and Fig. 1.6.7 shows a schematic track layout plan for each line.

(b) Platforms and passengers' overbridges

For the commuter service and the improved total transport service, raised platforms are essential to ensure the safety of passengers in stations where high speed and high frequency train operation is carried out and to cope with a large number of passengers smoothly.

Since commuters have to get off/on a train in a short time, it is desirable to minimize the number of steps. Consequently, the suitable height for a platform is considered to be 80 cm which is the very limit of construction regulation.

Moreover, since both the frequency and speed of trains will be enlarged, it is quite dangerous for passengers to cross tracks. As a result, in order to ensure the safe movement of passengers, it is necessary to build passengers' overbridges in major stations, as well as to raise platforms to prevent passengers from entering tracks..

Fig. 1.6.8 shows proposed raised platform for commuter electric railcars.

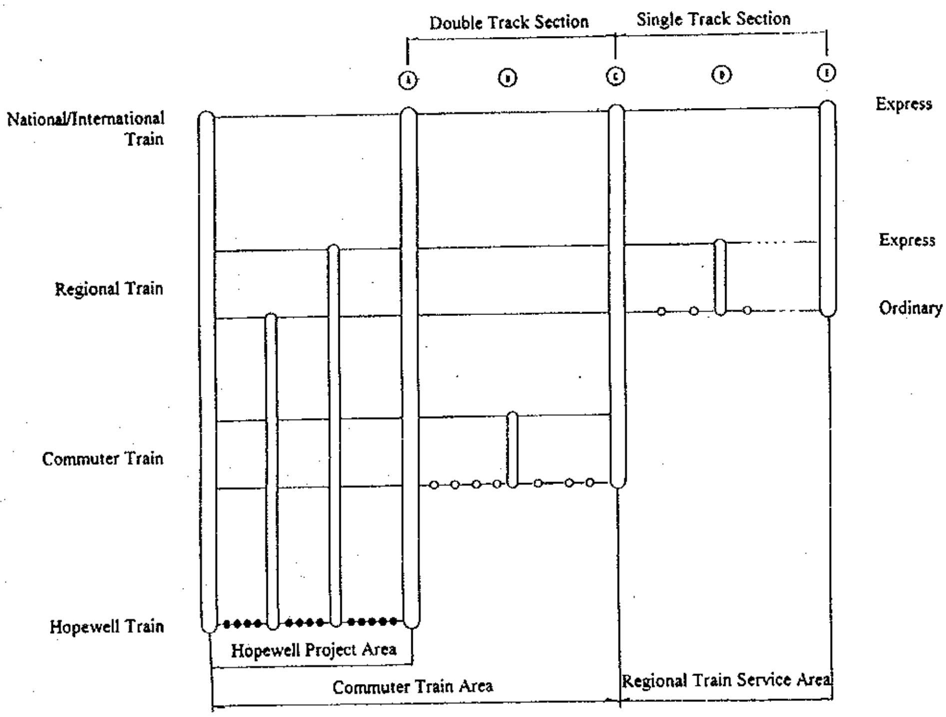


Fig.1.6.5 Train Operation Pattern

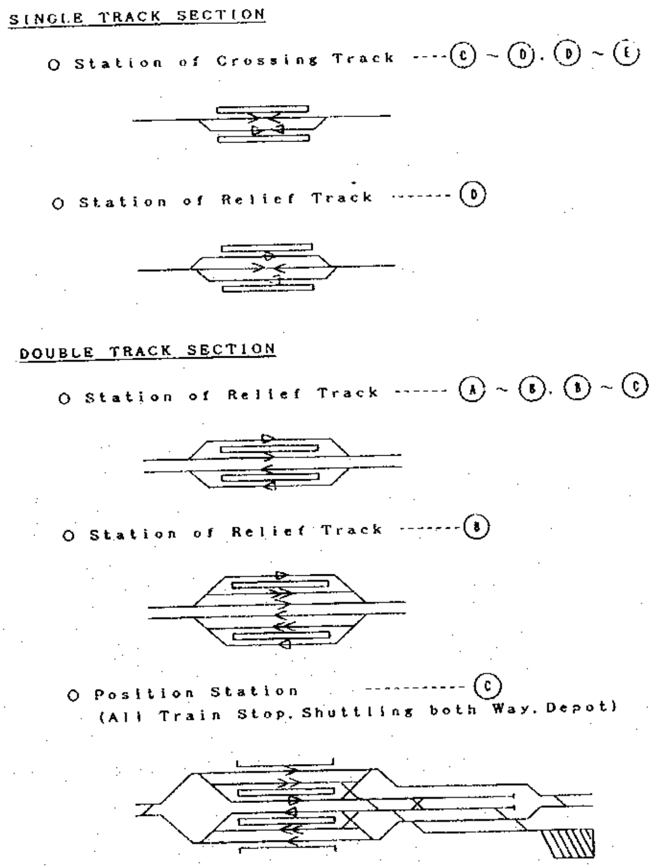


Fig.1.6.6 Station Track Layout Patten

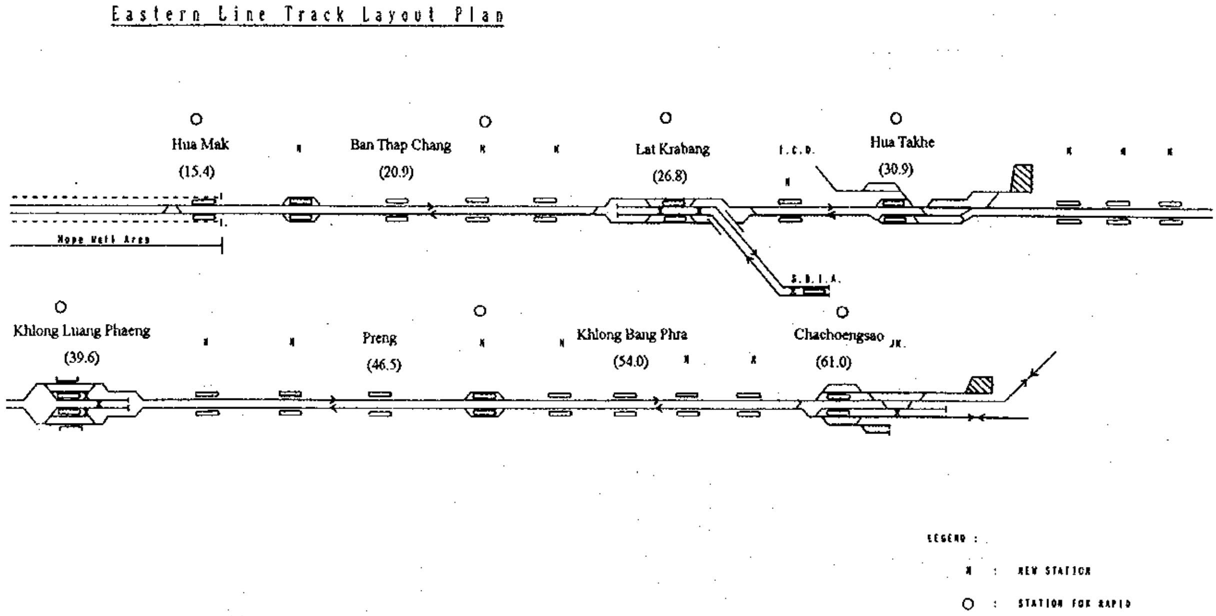


Fig. 1.6.7(1) Track Layout (1)

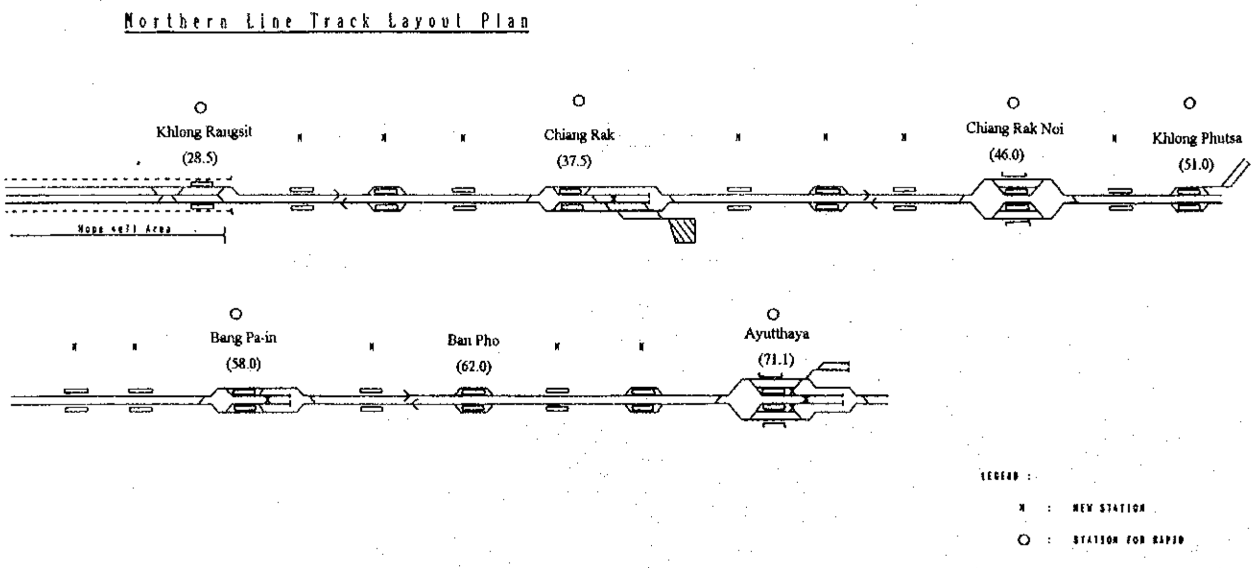
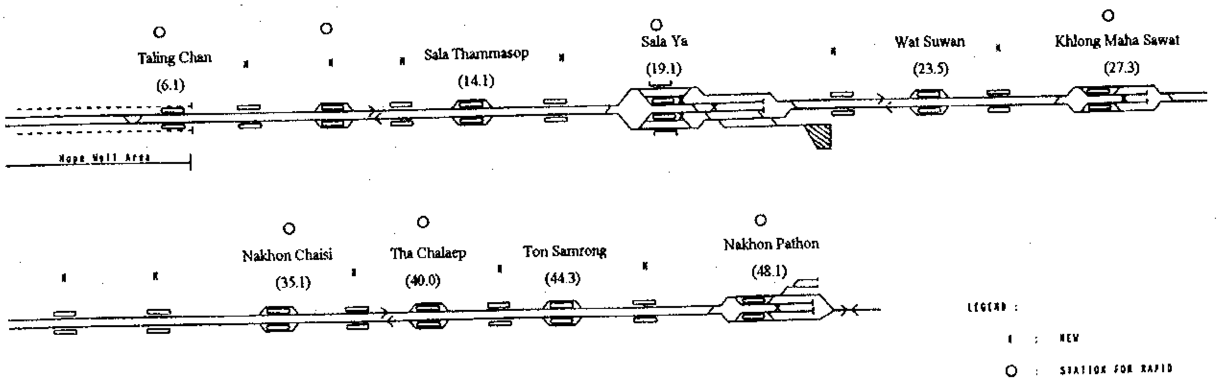


Fig. 1.6.7(2) Track Layout (2)

Southern Line Track Layout Plan



Mae Khlong Line Track Layout Plan

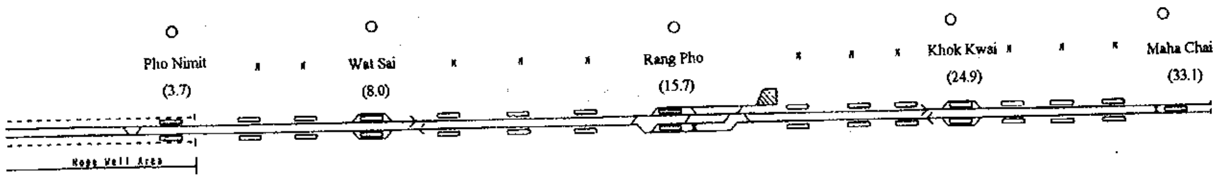


Fig.1.6.7 (3) Track Layout (3)

North Line Track Layout (After completion of triple tracking)

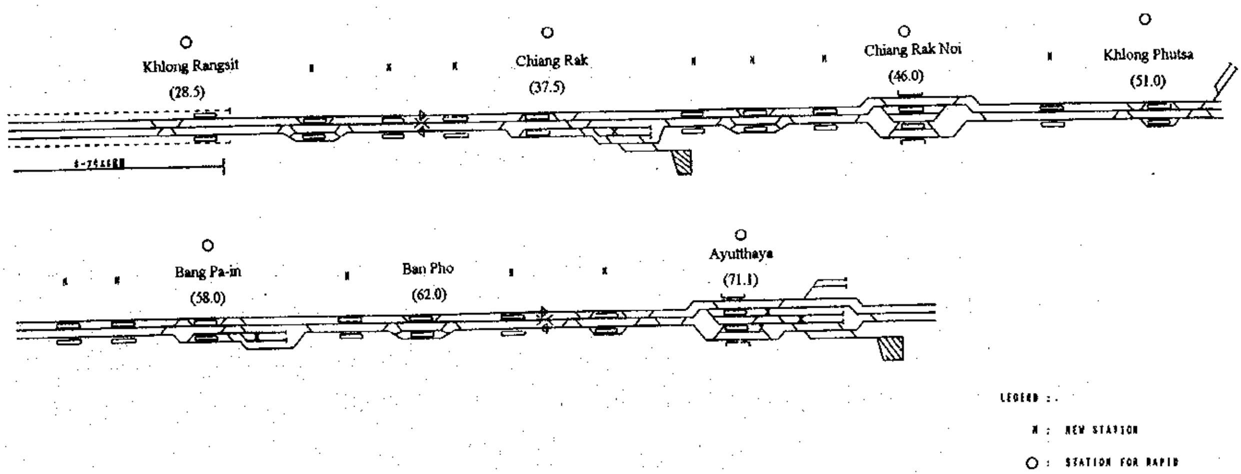


Fig.1.6.7 (4) Track Layout (4)

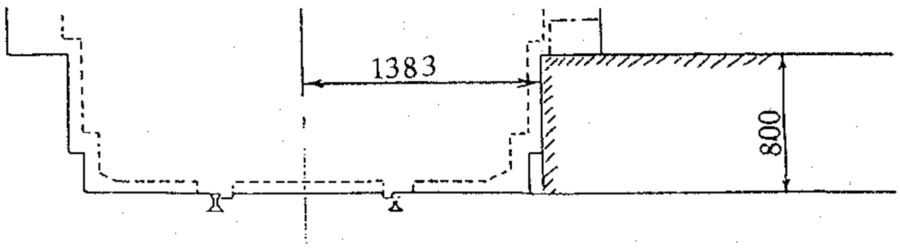


Fig. 1.6.8 Proposed Raised Platform for Electric Railcars

(c) Station building and commercial development

A railway station is a place used by many people as a travelers' terminal. If railways are to play the role of a full-scale transport means in the future, the number of the station users will grow rapidly. Without any specific measures taken by a railway organization, many passengers will just pass through stations as they are. However, if a station area is properly developed, the station will easily function as a commercial terminal. In fact Wong Wien Yai and Thon Buri have already become commercial terminals.

Because railways have a public nature in Japan also, it is difficult for railway companies to raise fares easily. Therefore, by running associated enterprises such as station buildings, they are trying to ensure stable earnings. It is said that a financially sound private railway company derives approximately 30% of its earnings from its associated enterprises.

Since the right-of-way in the city area of Bangkok is to be developed by Hopewell, there will be no room for the SRT to be involved in such development. However, with regard to its stations in major regional footholds, in addition to preparation of station plazas, the SRT should work on construction of station buildings and the invitation of commercial tenants so that its management may be stabilized and stations may be activated.

(2) Electrification

1) Selection of power system

The effect of electrification is roughly classified into the following.

- Effective use of energy
- Reinforcement of transport capacity
- Reduction of maintenance cost
- Improvement of service

(a) Effective use of energy

Based on trial calculation, if electric power generated with oil in a thermal power plant is transmitted to a substation with a transmission line and a locomotive is operated with electricity, the total thermal efficiency is 28 %, while that of the diesel locomotive is about 22 %. Electricity is better in energy-use efficiency and has also the advantage of causing less industrial pollution.

Further energy saving can be achieved by adopting a regenerative braking system, which feeds the braking energy of a train feed back to the overhead contact system.

(b) Reinforcement of transport capacity

Since an electric vehicle has a high power-weight ratio, its acceleration can be increased easily, and deceleration also can be increased without raising maintenance cost much by using an electric brake. Therefore, an electric vehicle can speed up. This is effective on an urban railway where the interval between stations is short. The number of train services can be increased by speed-up through electrification so that a frequent service is easily realized. Generally speaking, electrification can increase a line capacity by 10 to 40 %*, depending on the line conditions.

(c) Reduction of transport cost (cost reduction)

Low power cost, low vehicle maintenance cost, high vehicle operation efficiency and high productivity of crews are the reasons why transport costs can be reduced through electrification.

a) Vehicle maintenance cost

Since almost all the motive-power-generating parts of the electric rolling stock are maintenance-free except for some consumables such as a pantograph slider, their maintenance cost is low while that of diesel engines is high because they are exposed to high temperatures and have piston cylinders performing reciprocating motions. Repair of a diesel railcar costs approx. 30 %* more than that of an electric railcar. In addition, it requires 1.1* persons to maintain and inspect a diesel railcar while it requires 0.5* persons to maintain and inspect an electric railcar, which is less than half. As mentioned above, it can be said that an electric railcar is a motive-power unit which requires a very low maintenance cost. This fact greatly contributes to cost reduction and is one of the greatest effects of electrification.

b) Vehicle availability

In the case of electric railcars, supply of water, oil, etc. is not required, long distance operation is possible, and vehicle availability can be improved. Running-km per car per day of an electric railcar is 1.2* times longer than that of diesel railcars and that of the electric locomotive is 1.7* times longer than that of diesel locomotive, which shows a high vehicle availability. Putting it another way, the same traffic volume can be handled with less vehicles.

c) Productivity of crews

Productivity of crews can be expressed in train-kilometers per day per crew. The train-kilometer of the electric locomotive is 1.8* times longer than that of the diesel locomotive and that of the electric railcar is 1.1* times longer than the diesel railcar, which indicates that electrification improves the crew-kilometer per crew member.

(d) Improvement of service

An electrified train does not generate any exhaust fumes, provides a comfortable trip for the passengers, and minimizes pollution such as noise, exhaust gas, etc. Speed-up through electrification will shorten travel times required, which will encourage passengers to travel more frequently, increasing revenues. Past results show that the encouragement caused by electrification is 5 - 20 %* depending on the condition of sections.

Table 1.6.2 shows a comparison between the electric railcar and the diesel railcar.

* Remarks: Figures * are based on actual results and include the proper operating conditions of the lines. However, it can be said that the trend shown is accurate.

2) Economic comparison between electrification and dieselization

In contrast to diesel, electrification requires a large investment for ground facilities and their maintenance. These investment and maintenance costs tend to increase as the traffic volume increases, but the majority is considered to be fixed cost which is irrelevant to the traffic volume. On the other hand, power cost and vehicle maintenance costs are proportionate to the traffic volume.

Therefore, whether electric operation or diesel operation is more advantageous greatly depends on the traffic volume in the specific section.

Consequently, a traffic volume break-even point exists. That is, an economic calculation is made by calculating the balance of the initial investment amount (investment in electrification - investment in dieselization) and the balance of the annual cost (annual cost of dieselization - annual cost of electrification).

According to a practical calculation in Japan, electrification is more advantageous in a section where the number of trains is 50 or more on a single-track and 80 or more on a double-track.

3) Selection of electrification system

At present, various electrification systems are adopted. However, except in the case of extending the existing electrified section, a single-phase commercial frequency AC (alternating current) system or a DC (direct current) system is practical based on up-to-date technology from around world.

(a) Single-phase commercial frequency AC system

A single-phase AC system is divided into several types. However, recently a commercial frequency has been adopted in most cases. This is because power with the commercial frequency received from a general transmission line can be supplied to an electric railcar as it is without converting the frequency. Therefore, it is enough to install simple facilities such as only transformers in a substation.

Furthermore, since an electric railcar is equipped with a transformer, a voltage can be selected freely in the car. For this reason, a comparatively high contact wire voltage can be adopted. As the contact wire current may be small, the voltage drop is small and the interval between substations can be made longer. Consequently, the number of substations may be reduced. If a voltage drop causes any problem, voltage can be recovered relatively easily by installing a series capacitor in a substation or overhead contact system to compensate for the impedance of the circuit.

On the other hand, the AC system may cause communication inductive interference to communication lines existing nearby. It is necessary to take measures to reduce this. Furthermore, since single-phase power for an electric railway is received from a general three-phase transmission line, if a short-circuit capacity of the three-phase power source system is small, problems of voltage unbalance and fluctuation may arise. It is necessary to pay attention to this matter in selecting a power source.

Table 1.6.4 shows a comparison of technological features between the single-phase commercial frequency AC system (25 KV) and the DC system (1,500 V).

A variety of current feeding systems have been put to practical use because of differences in how to take measures against the above-mentioned communication inductive interference, how to supply a large amount of electric power to the overhead contact system, etc. Table 1.6.5 shows their classification and features.

(b) DC system

The DC system is to install in an electric railway substation electric power transforming facilities and a silicon rectifier to convert high voltage AC power received from a general electric power system into low voltage DC power and to transmit the DC power through an overhead contact system. An electric railcar is driven by spending this low voltage DC power.

The DC system has been adopted for a long time in various countries of the world. Since technological restrictions such as insulation design and rectification are placed on DC traction motors in this system, excessively high voltage is not adopted and 3,000 V is the world recognized possible maximum voltage.

In the DC system, a voltage drop increases and the interval between substations cannot be made so long because the contact wire current of the DC system is greater than that of the AC system.

Furthermore, the greater the current is, a larger current capacity of a contact wire is required. Generally, a feeder is established parallel to a contact wire to reduce a voltage drop and to increase the current capacity. On the other hand, since the voltage is low, the overhead contact system and devices can be easily insulated and the insulation separation in a tunnel, bridge, etc. can be small. The DC system is technologically easy because it has a long history coupled with rich experience.

(c) Selection of electrification system

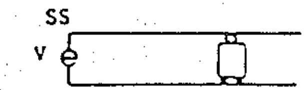
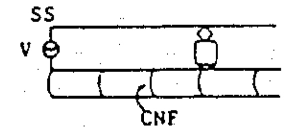
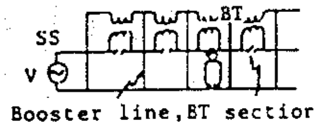
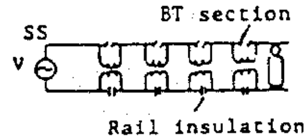
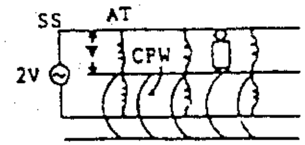
As for an electrification method for this project, the commercial frequency (50 Hz) single-phase AC 25 KV system is selected, based on the following reasons.

- AC electrification cost (transmission line, substation, overhead contact system, etc.) is lower than that of the DC electrification system. For example, if the AC AT feeding system is adopted, only one substation is sufficient. However, if the DC system is adopted, about 30 substations are required and the total length of the transmission line

Table 1.6.4 Comparison between Commercial Frequency Single-phase AC 25KV System and DC1,500V System

		Commercial frequency single-phase AC 25KV system	DC 1,500V system
Ground facilities	1. Substation	1. The construction cost is low. (1) The interval between substations is long (100km in the case of the AT system), and many substations are not required. (2) The substation facilities are simple because a transformer is the main facility.	1. The construction cost is high. (1) The interval between substations is short (approx. 10-15km), and many substations are required. (2) A transforming device from AC to DC is required and the substation facilities are complicated.
	2. Transmission line	2. The construction cost is low because many substations are not required.	2. The construction cost is high because many substations are required.
	3. Overhead contact system	3. A thin feeding line is sufficient because the load current is small. In addition, the trolley line does not wear quickly and the cost for replacement is small.	3. A large feeding line is required because the load current is large. In addition, the trolley line wears quickly and the cost for replacement is large.
	4. Communications equipment	4. Since the load current contains harmonics, the problem of communication inductive interference arises. Therefore, it is necessary to replace the bare communication lines by underground cables and install auto-transformers, or boosting transformers, etc..	4. Installation of a filter in the substation suppress the communication inductive interference.
	5. Comparison of copper amount	5. Only a small amount of copper is required.	5. A large amount of copper is required.
	6. Power source	6. The three-phase power source unbalance is caused due to single-phase load so that some measures must be taken against it.	6. The problem of three phase power source unbalance does not arise.
	7. Feeding voltage	7. A transformer can be used for an electric car and high voltage can be utilized.	7. Since the insulation design of the traction motor and DC transforming device is restricted, high voltage cannot be used.
	8. Countermeasures against voltage drop	8. The voltage drop can be easily compensated by installing a series capacitor and a voltage compensator.	8. With the increase of load, it is necessary to increase feeding lines and newly establish substations.
	9. Insulation separation	9. The insulation separation is large because of high voltage, and generally the tunnel cross-section is large.	9. The insulation separation can be small because of low voltage.
On board facilites	1. Voltage transformer and current transformer	1. It is necessary to provide a transformer and a rectifier and high voltage insulation for a car which requires higher investment cost and maintenance expenses for a car.	1. They are not required.
	2. Accessories	2. A low-voltage AC power source can be obtained freely with a voltage transformer, and a simple and rigid induction motor can be utilized. Electric facilities such as fluorescent lamps and air-conditioning units are also simple.	2. A DC machine is driven with a trolley voltage and the structure is complicated. Electric facilities such as fluorescent lamps and air-conditioning units are also complicated.

Table 1.6.5 Classification and Features of Commercial Frequency Single-phase AC Feeding Systems

Name		System Diagram		Features
Simple feeding system	(1) Basic form (T - R)		Contact wire Rail	1. This is the simplest composition of feeding circuit. 2. There is no section such as BT section. 3. The communication inductive performance is poor. 4. Protective measures such as for insulator flash over are necessary. 5. The rail electric potential is logically higher than those of other feeding systems.
	(2) With NF (T-R-NF)		Contact wire Rail NF	1. If NF is installed, line impedance and rail electric potential becomes less than that of (1) basic form. 2. There is no section such as BT section. 3. The screening effect against communication induction is greater than that of (1) basic form.
Boosting transformer (BT) feeding system	(3) With NF		NF Contact wire Rail	1. Communication induction reducing effect is great. 2. BT sections are required. 3. The BT interval is usually 4 - 6 km.
	(4) Without NF		Contact wire Rail	1. NF can be omitted while the BT characteristics are utilized. 2. The communication induction reducing effect is slightly inferior to the case of (3) with NF. 3. BT sections are required. 4. Rail insulations are required. 5. Protective measures for insulator flashover are required.
(5) Auto-transformer (AT) feeding system			Contact wire Rail Feeder PW	1. Since the feeding voltage (SS transmission voltage) can be made higher than the contact wire voltage, this is suitable to supply power to large load. 2. The SS interval can be made longer than those of other current feeding system. 3. The communication induction reducing effect is large. 4. There is no section such as BT section. 5. The AT interval is 10- 15 km. 6. It is necessary to establish a feeding line of the same insulation class as that of the trolley line along all the sections.

from the power supply network of the electric power company is longer. Consequently, less construction cost is required.

- At present, the SRT is promoting modernization of signalling facilities and has adopted a DC track circuit system. When the DC electrification system is adopted, a track circuit must be completely replaced with that of another system, but for the AC electrification system, the DC track circuit can be used as it is and only a minor modification is sufficient.

- This is the first electrification for the SRT and it is not necessary to consider the relationship with the existing electrification system. Therefore, it is advantageous to adopt the AC 25 KV 50 Hz which is now the mainstream of the electrification system and highly popular all over the world in the aspect of manufacturing electric railcars and constructing ground facilities.

Furthermore, substations of 50 Hz, 500 KV and 230 KV, etc. and transmission networks which are a nucleus of general commercial electric power have been established over this project area. Electrification of the AC 25 KV, 50 Hz system has no major problems in supplying electric power and it is quite easy to install large-size railway substations.

As mentioned above, the commercial frequency (50 Hz) single-phase AC 25 KV electrification system has a simple feeding system, AT feeding system and BT feeding system. Among these electrification systems, a system is selected taking into consideration many factors including the state of the power supply network, countermeasures against communication inductive interference, construction cost and maintainability of facilities.

- First of all, the allowable feeding distance is approx. 60 km in the simple feeding system, approx. 110 km in the AT feeding system, and approx. 50 km in the BT feeding system. The longer the interval between substations becomes, the less the number of substations is, the more freely the power source receiving point can be selected and the lower the construction cost required for the substation facilities is. Incidentally, if the simple feeding system or the BT feeding system is adopted in this project, 4 substations are required while only one substation is sufficient if the AT system is adopted. Accordingly, the construction cost of a transmission line as well as substation cost is lower.

On the other hand, as for the state of the electric power network in Thailand where general commercial electric power is supplied, a strong electric power network has been completely set up so that it does not cause any problems of voltage unbalance or voltage fluctuation due to a single-phase load of the electric railways.

- Next, as for countermeasures against the communication inductive interference, the aerial communication cables for the general public are set up along the railways in Bangkok. Therefore, it is necessary to adopt a system which is not likely to cause communication inductive interference, that is the AT feeding system or the BT feeding system. In areas not yet developed at present, with future advancement of the urban development along the railways, some countermeasures against communication inductive interference will be required. It is advisable to avoid adopting the simple feeding system.

- From the viewpoint of maintenance of facilities, the simple feeding system is the simplest system and it is excellent in maintainability. The AT feeding system requires AT over the whole route as well as a feeding line of the same class as that of a trolley line, so that this system has a more complicated circuit composition than the simple feeding system.

The BT feeding system requires BT and BT sections, so that its feeding circuit composition is complicated. Furthermore, if some measures to suppress arc generated in a BT section are required, a catenary structure will be further complicated and its maintenance will require much more manpower.

After considering all the matters mentioned above, it is the most advantageous to adopt the AT feeding system in this project.

(d) Power system and influence of the electrification on power source

The present situation (1992) of the electric power supply in Thailand is summarized as follows:

The installed capacity is 11,033 MW, which is mainly generated by thermal power plants. The peak generation is 8,877 MW, and the gross generation is 56,020 GW, and they have increased by 10.3 % and 13.8 %, respectively, compared to those in 1991.

The electric power demand in 1991 was 8,045 MW and the future power demand estimate will be 13,075 MW in 1996, 19,000 MW in 2001, and 25, 515 MW in 2006. The electric power policy of the Thai Government to cope with this increase in demand is to install facilities so that a margin of 15 % or more always can be secured against the demand. (Figs. 1.6.9 and 1.6.10.)

The transmission system consists mainly of 500 KV and 230 KV trunk lines and the power distribution network is composed of 115 KV and 69 KV distribution lines. The transmission line of each class has been set up mainly in Bangkok. Fig. 1.6.11 shows the power supply network, present state of the transmission network, and future plans in Thailand and the metropolitan area. It is concluded that the power supply required for the electrification in this project does not cause any problem.

(e) Feeding system and location of substations and other facilities

Fig. 1.6.12 shows the location of a traction substation and sub-section posts in the electrification plan of this project. Bang Sue was selected as the location of the traction substation considering that power should be received from general commercial substations with as large a short-circuit capacity as possible, the transmission distance should be made as short as possible, and a traction substation should be located near the middle of the electrification.

Based on trial calculations, leaving a little leeway, the capacity of the main transformer will be 35 MVA.

It is desirable that two main transformers, one with a capacity of 20 MVA and one with a capacity of 15 MVA, are installed for normal use and a main transformer with a capacity of 20 MVA is installed as a stand-by.

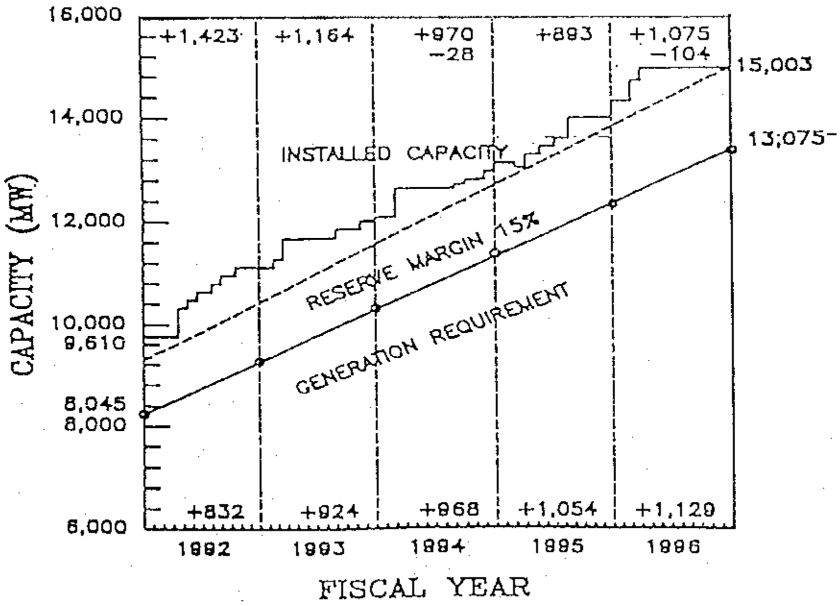


Fig. 1.6. 9 Installed Capacity and Peak Generation Profile in the 7th Plan

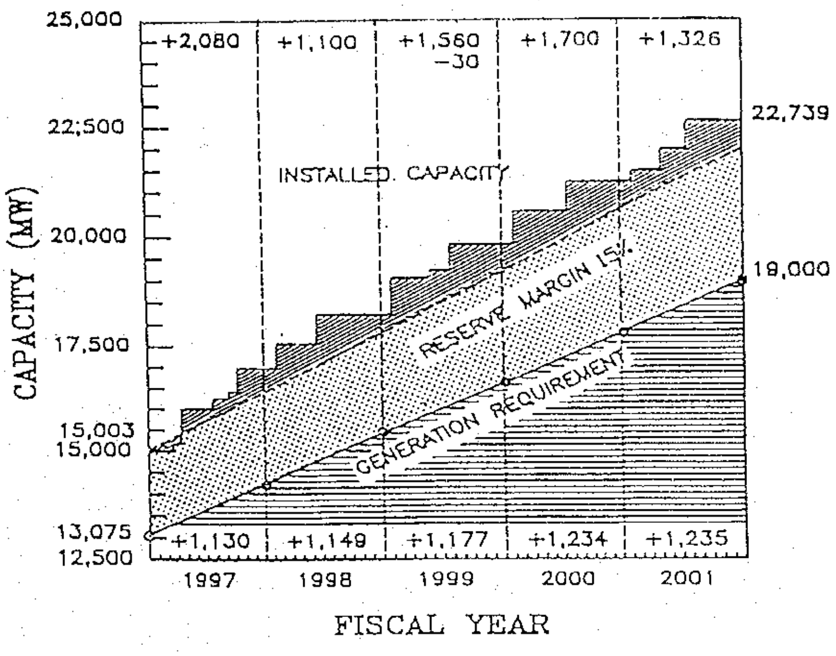


Fig. 1.6.10 Installed Capacity and Peak Generation Profile in the 8th Plan

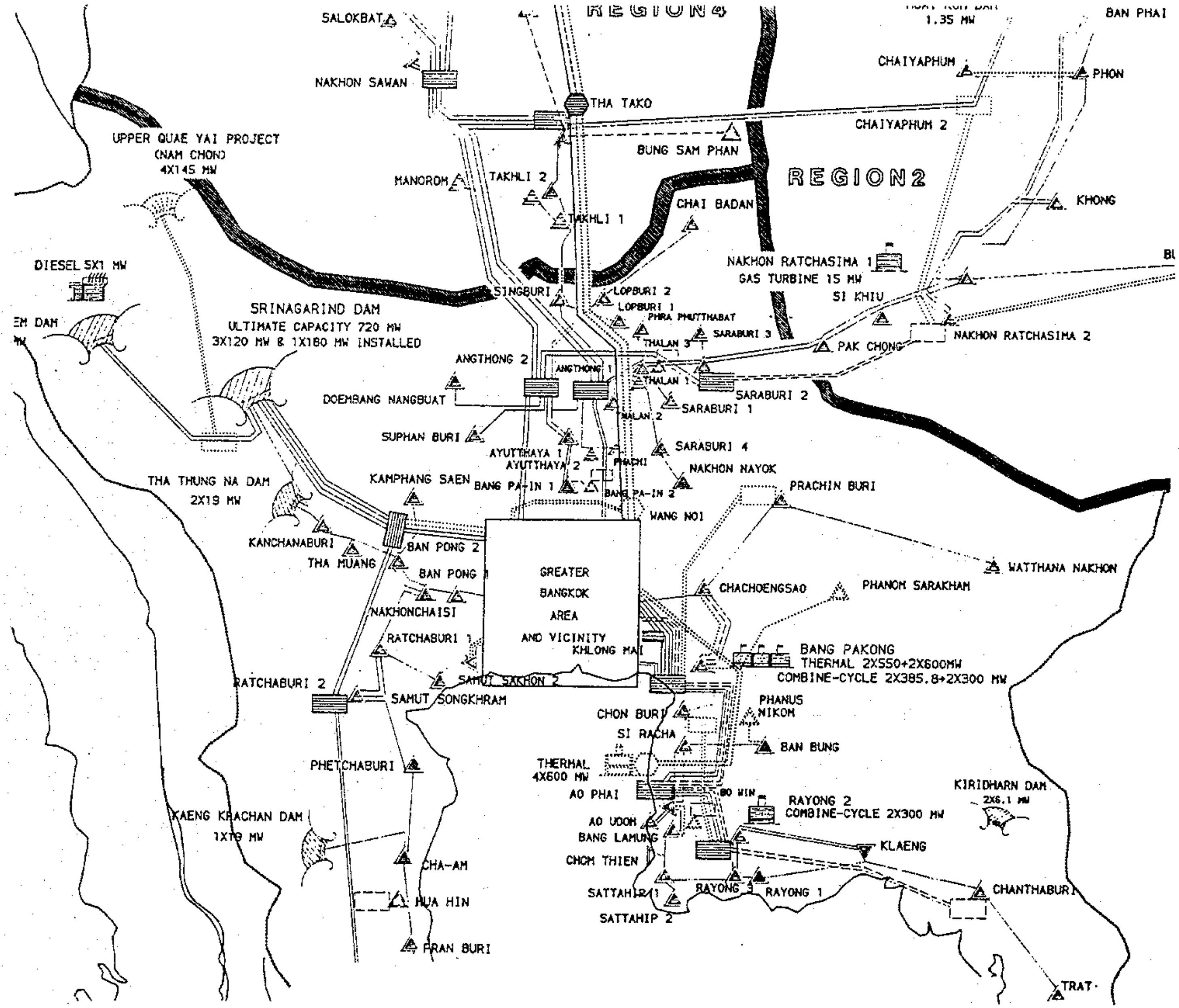


Fig. 1.6.11(1) Public Power Supply System in the Study Area

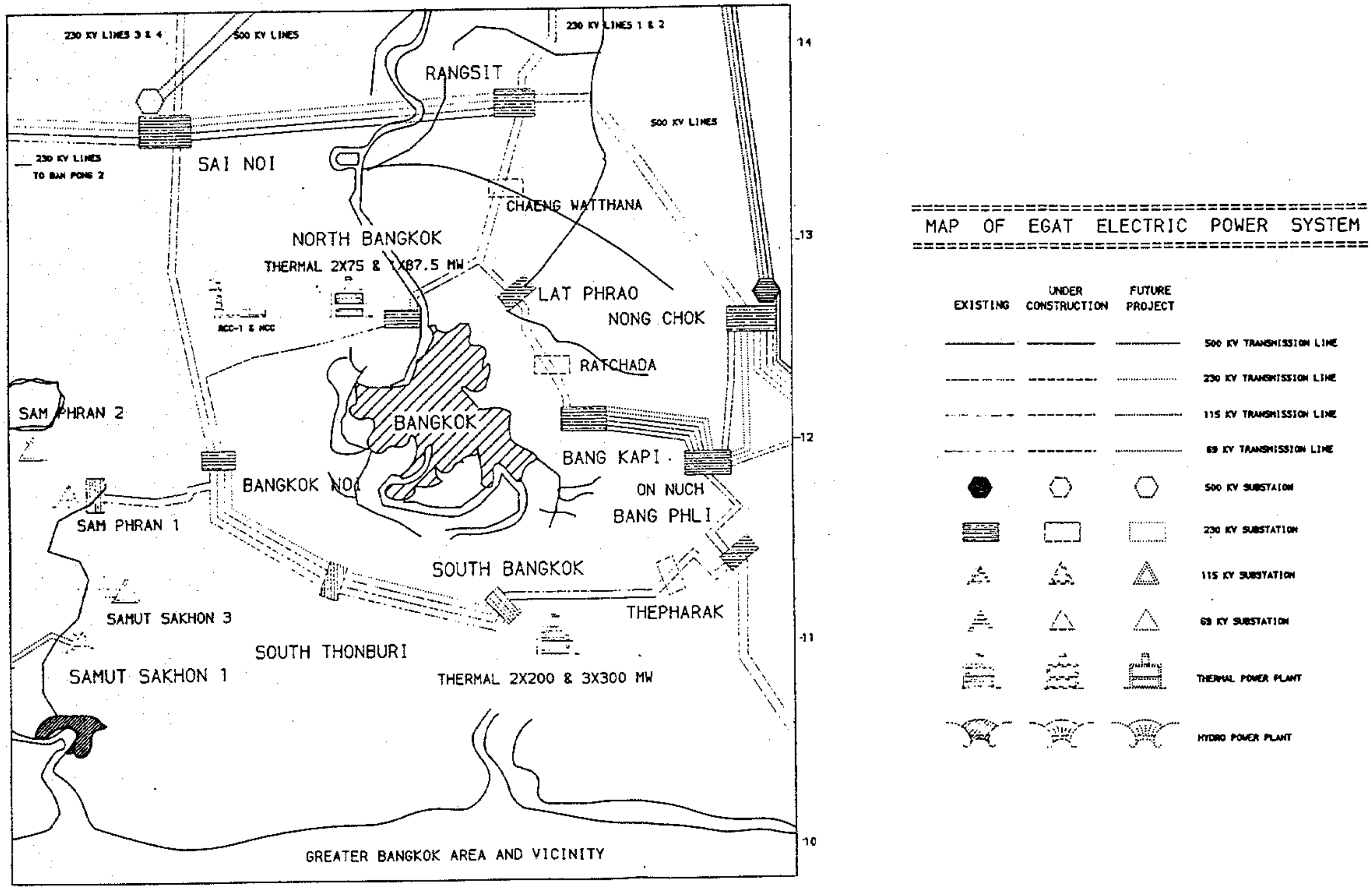


Fig. 1.6.11(2) Public Power Supply System in the Study Area

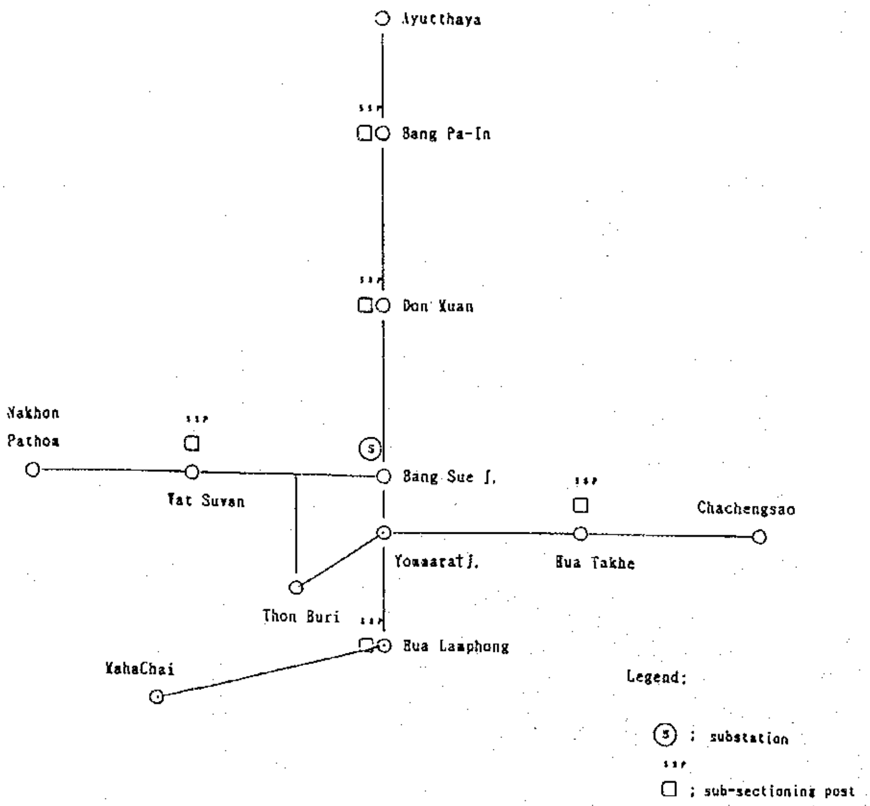


Fig. 1.6.12 Layout of Substation and Sub-sectioning Posts

(3) Signalling and telecommunications

The commuting sections with a great volume of passengers are planned to be electrified. Therefore, all the signalling facilities in the section to be electrified will be automatized because the automatic signal facilities provide the largest line capacity and the highest safety. And at the same time, the CTC, which is the most efficient in controlling the train services, is to be adopted.

1) Improvement in facilities accompanied by electrification

(a) Signalling facilities

Generally, traction current passes irregularly in a AC electrified section, which constitutes a factor which affects signal facilities in various ways.

a) Track circuit

It is necessary to take measures because a thyristor-controlled car and a VVVF inverter-controlled car, which has recently been developed, generate complicated higher harmonics unproportionate to the fundamental current frequency.

Furthermore, when AC electric rolling stock turns on a air-blast circuit breaker, a rush current is generated as a transient phenomena due to the exciting current of the onboard main transformer. Therefore, it is essential to design the DC track circuit paying full attention to the rush current. A basic countermeasure against interfering current is to improve S/N. Measures to improve S are to review the track circuit system, increase transmission output, improve the transmission equipment, increase receiving current, shorten the track circuit, etc. N can be reduced by improving the balance factor of the track circuit, improving the vehicles, etc.

DC track circuit has been adopted in SRT's re-signalling projects as the most economical type taking into account a future AC electrification plan. However, the following modifications are necessary: increase transmission output, shorten the track circuit length, convert the present DC track circuits to the single-track system to pass traction current, and take countermeasures against a surge current.

b) Inductive interference

Since a high voltage of 50 Hz is used for the overhead contact system in the AC electrified section, induced voltage and induced current caused by electrostatic induction or electromagnetic induction are generated in the signalling equipment such as a block circuit, signal control cables, signal wires and point levers, etc. which are parallel and adjacent to the overhead contact system. Furthermore, an electromagnetic induction interferes with the track circuit close and parallel to the overhead contact system.

Table 1.6.6 shows influence exerted upon these signalling facilities and countermeasures against it in an AC electrified section.

Table 1.6.6 Induction Interference with Signal Facilities in AC Electrified Section and Countermeasures against It

Type of induction	Induced articles	Reason for interference	Measures to be taken
Electrostatic induction Electromagnetic induction	• Cable • Bare wire • Signal wire • Point lever, etc.	A man may receive an electric shock (Dangerous voltage)	• Transferring cable and bare wire, shielding, and cabling • Inserting an insulation section into the wire equipment and grounding
Electromagnetic induction	Track circuit	The track relay may malfunction	• Inserting a resistor into the receiving end of the track circuit • Changing the track circuit system

(b) Telecommunication equipment

a) Induction measures to communication line

If a power line of an electric railway or the like exists close to a telecommunication line, some electric energy of the power line is transmitted to the telecommunication line and that generates a dangerous voltage.

The effect of the power line on the communication line is called induction, which is divided into 2 types; electrostatic induction and electromagnetic induction.

The limiting value of an induced voltage in accordance with the Comite Consultatif International Telegraphique et Telephonique (CCITT) is shown in Table 1.6.7.

Table 1.6.7 Limiting Value of Induced Voltage in Accordance with CCITT

Item	Limiting value	Remarks
Dangerous induced voltage in abnormal condition	430 V	
Dangerous induced voltage in normal condition	60 V	
Induction noise voltage	1 mV	Weighed psophometric noise electromotive force
Discharge current of electrostatic induction	15 mV	

Since a commercial frequency (50 or 60 Hz) of a high voltage (20 or 25 kV) is used in the AC electrification, a strong induction is generated. This induction not only generates a noise but also may be hazardous to humans. For this reason, in the case of AC electrification, a filter is inserted into electric cars to suppress higher harmonics as a measure on the induction side. In addition, on the feeding circuit side, an auto-transformer (AT system) is used, or a boosting transformer and a negative feeder are equipped (BT system) to reduce induction.

On the induced side, accumulation of induced voltage is prevented by using a shielding cable or optical cable for bare wires as well as by inserting a repeating coil, insulating coil and a draining coil.

Firstly, this induction should be minimized on the induction side, then some measures should be taken on the induced side. Electric cars also cause induction due to a phase-controlling thyristor so that measures are taken for higher harmonics. Although these measures are taken, it is impossible to completely eliminate the induction interference. In this case, it is necessary to take the induction interference measures on the induced side.

i) Measures on the feeding side

As mentioned above, the BT system or AT system has a greater effect to reduce induced voltage than the simple feeding system.

ii) Measures to be taken on electric railcars

Since higher harmonic current is generated in the traction current when a thyristor-controlled car runs in the AC electrified section, a filter is installed, the number of divisions on the secondary side of the main transformer increases, and accumulative control is performed on the electric car.

On the other hand, the equivalent noise current (evaluated higher harmonic current) of an electric car is used in calculating noise voltage. Since the inductive noise voltage is proportionate to the equivalent noise current, it is necessary to minimize this equivalent noise current on the electric car side.

iii) Measures on the telecommunication side

In the induction predictive calculation formula, the coefficient of mutual induction, length of the telecommunication line, shielding coefficient of the telecommunication cable and parallel length to the power line are the constants determined by the facility condition of the telecommunication line. If these constants are held down, the induced voltage can be reduced. The following possible measures can be taken.

- Using a shielded cable or optical cable
- Making the separation between feeding circuit and telecommunication line wider
- Shortening the length of the telecommunication line
- Inserting a circuit which has a high impedance to the ground and a low impedance between lines

Using a carrier system with a high frequency band which is not affected by the induction noise voltage. Or as for induced voltage in abnormal condition, discharging abnormal voltage by installing a lightning arrester, draining coil, etc.

b) Circuit composition

Long distance circuits will be borrowed from the COMLINK optical telecommunication line now under construction in the SRT and as a medium distance line connecting stations, the same system as that of the optical cable and underground shield cable system planned in the CTC section of the northern line now under construction and in the new line section will be adopted. A metallic cable will be used for a local line in station yards and a short distance line and measures to prevent induction interference will be taken. Fig. 1.6.13 shows the sections where the optical cables are laid in the electrification target area.

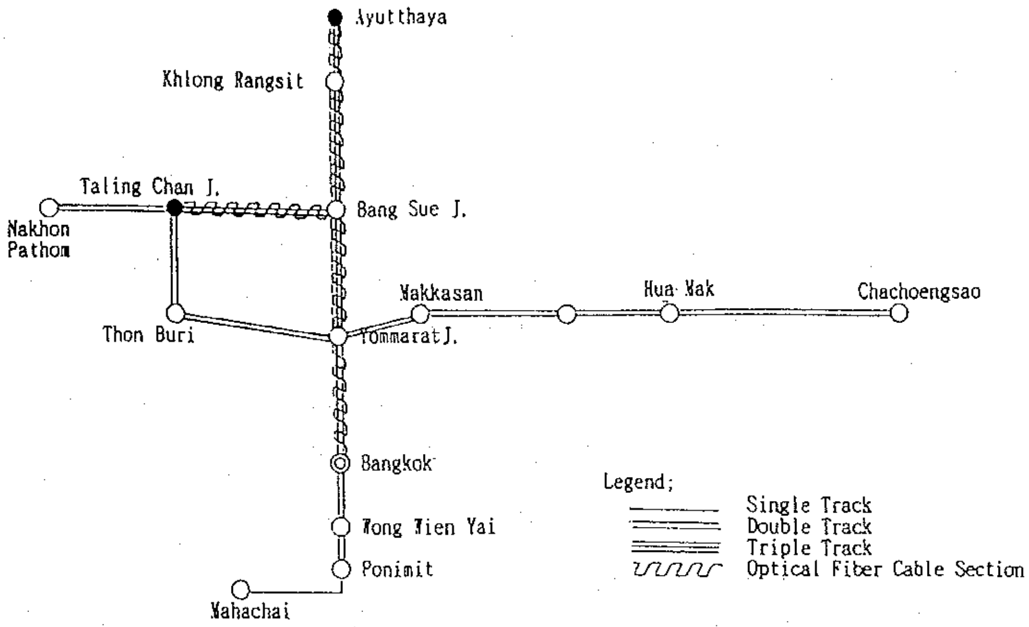


Fig. 1.6. 13 Optical Cable Drawing

2) Improved and newly-established facilities to carry out this project

(a) Signalling facilities

a) Block instrument

If two or more trains are operated on the same line, it is necessary to properly control the operation and keep these trains at regular intervals for their mutual safety. Two methods are available for this purpose; the time interval method and space interval method.

The time interval method is to operate trains keeping a given time. This method does not require a block instrument, but it is not applicable to a high-speed and high-density train service section. The space interval method is to operate trains keeping the distance between trains constant and various methods are used.

A block instrument affects the line capacity, degree of safety, etc. Therefore, it is advisable to adopt a block instrument which meets the requirements of electrification which aims to reinforce transport capacity. The block instrument has evolved from a telegraph system and a tablet and ticket block system to a tablet block system, then from a tokenless block system to an automatic block system. During this period, the frequency of train operation has increased and the degree of safety has improved. Table 1.6.8 shows a comparison of the main block systems.

It is necessary to study the following matters as criterion in determining a block system.

- Line capacity: Is it enough to set one block section in two adjacent stations for transport demand, particularly in a single-track section?

- Improvement in safety: Is the best system adopted from the viewpoint of the frequency of train operation in a relevant line, labor-saving and line condition?

- Application of CTC: Is the introduction of CTC planned in the future?

An automatic block system will be adopted by which a maximum number of trains can be run because, in the target section commuter trains will be run at high frequency in this project. Addition of facilities which enable a bi-directional run for maintenance work and failure of facilities is available.

b) CTC

The CTC (Centralized Traffic Control) is a kind of code transmission device to collect train information in a central control center and at the same time remote-control signalling facilities of each station. A train despatcher can directly perform a route setting in each station with this device. The train position display function provided by CTC can be used for various purposes. For example, this function not only facilitates a train operation control but also enables the monitoring of on-site facilities and provides passengers in each station with train service information (through display, broadcasting, etc.). Fig. 1.6.14 shows the composition of CTC.

The same CTC system as that of the Northern Line which is now under construction in the SRT will be introduced in other electrified sections.

Fig. 1.6.15 shows the signal installation just before this project starts.

Table 1.6.8 Comparison of Block Systems

	Tablet block system	Tokenless block system	Electronic block system	Automatic block system
Applicable section	Single-track section	Single-track section and low-density service section in a double-track section	Single-track section	Double-track section and high-density service section in a single-track section
Block section	One block between stations	One block between stations	One block between stations	Several blocks between stations
Handling of block instruments	Receiving and giving tablets by operation of both station-masters	Both station masters operate a blocking lever	Motorman's operation	Both station masters operate a traffic lever in a single-track section and need not do so in a double-track section
Train detection method	None	Short track circuit (Check-in and check-out)	Electronic token and track circuit	Two or more continuous track circuits
Interlocking with signal	None	Interlocked with an oncoming train with a blocking lever	A block instrument and signal facilities are incorporated	A block instrument and signal facilities are incorporated. An oncoming train in a single-track section is interlocked with signal facilities by a traffic lever.
Degree of safety	B	B	A	A
Running efficiency	D	C (Single-track)	B	A
Expandability	None	None	A cab signal is simple. A simple interlocking device is built in. A CTC terminal is built in.	Applicable to CTC
Basic circuit element	-	Relay	Microcomputer and IC	Relay
Circuit for blocking	2 wires For directional circuit in a single-track section	2 wires For directional circuit in a single-track section	2 wires Can be easily shared with a CTC circuit. Conversion to the radio system is easy.	2 wires For directional circuit in a single-track section
Construction cost	-	Low	Medium	High

Note) Degrees of safety and running efficiency : A > B > C > D

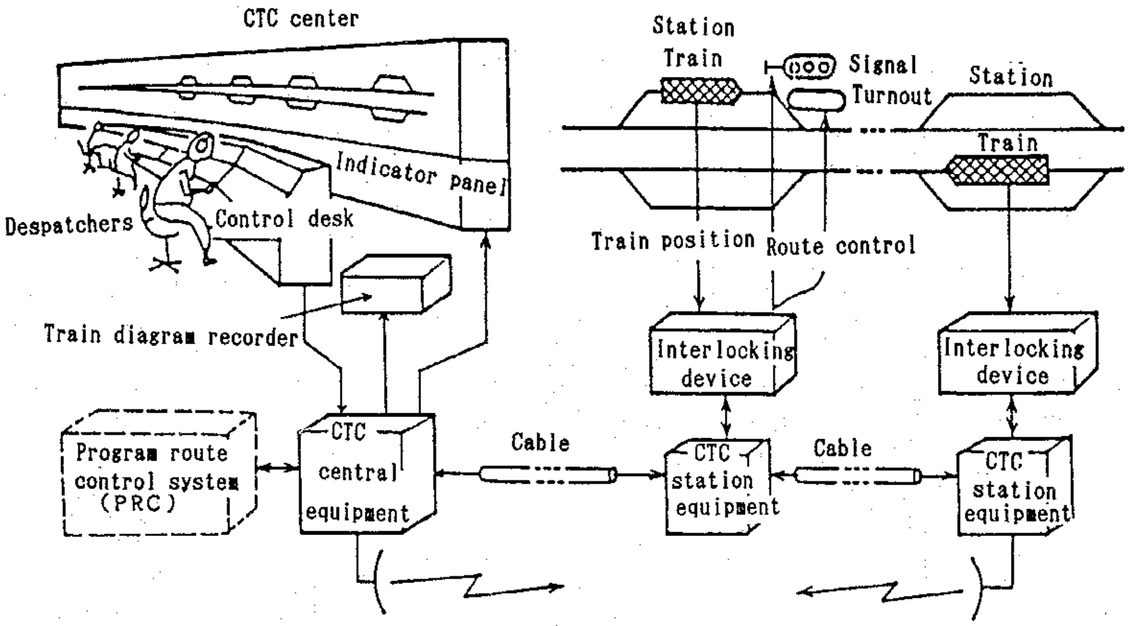


Fig. 1.6.14 CTC System Composition

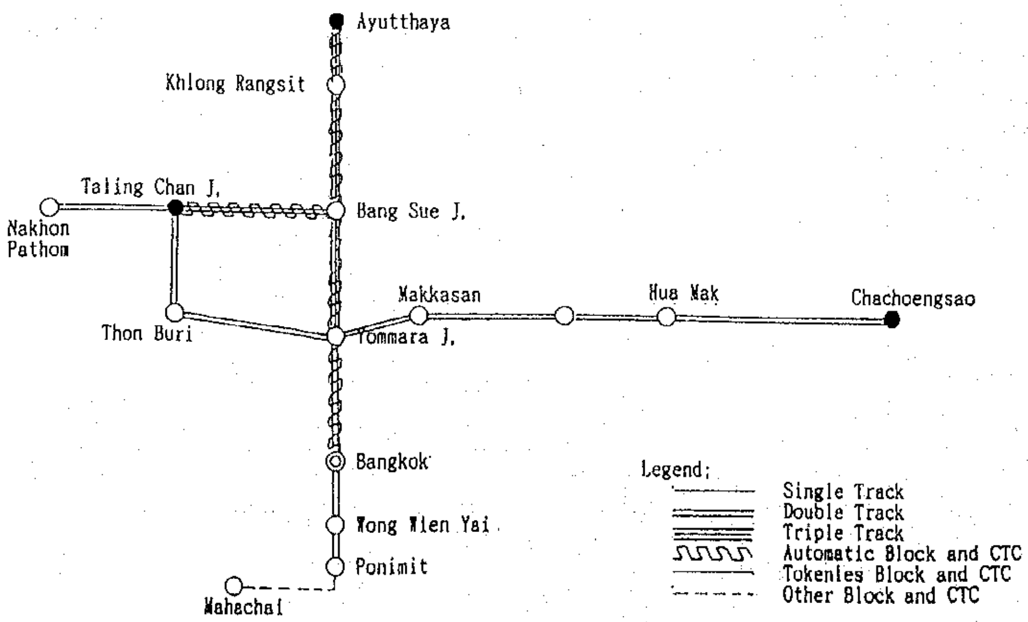


Fig. 1.6.15 The Signal Installation Just before this Project Starts

c) ATS

To further enforce rules of operating safety and observance of lineside signals, provision of a warning device or a control system in the locomotive cab and operation in conjunction with the lineside signals may further improve safety and encourage operation of trains at their maximum safe speed without compromising safety.

It is not usual to provide such systems on "low speed" lines, but it is a worthwhile consideration when train speeds are higher or to be increased, or when other conditions where a driver's misjudgement or fatigue etc., give rise to situations which the signalling system itself cannot guard against.

The options which would provide the most simple and cost-effective systems are:

a-type; A system of automatic warning or
b-type; A system of control operative when the driver ignores the stop signal or
c-type; A combination of warning and control,

based on an "intermittent" as opposed to a "continuous" system, and useing trackside inductors controled by signalling equipment inductively coupled to train-mounted equipment.

d) ATS-P type

In the above-mentioned 3 types, only an alarm is given when a train approaches a warning signal, or activates an emergency brake when a train passes a signal displaying a stop. Furthermore, they are designed so that the equipment is activated uniformly at the same place for trains with a different speed and a different braking distance.

The ATS-P compares the train speed with a stop pattern prepared based on the information from a ground coil installed before a stop signal aspect, turnout, curve, or speed restricted point and activates a maximum normal brake. Fig. 1.6.16 shows the system composition.

The signal aspect information and the distance information from a ground coil to a stop signal are transmitted to the ground coil. When a train passes above the ground coil, the train prepares a stop pattern peculiar to the train based on the information of the distance to

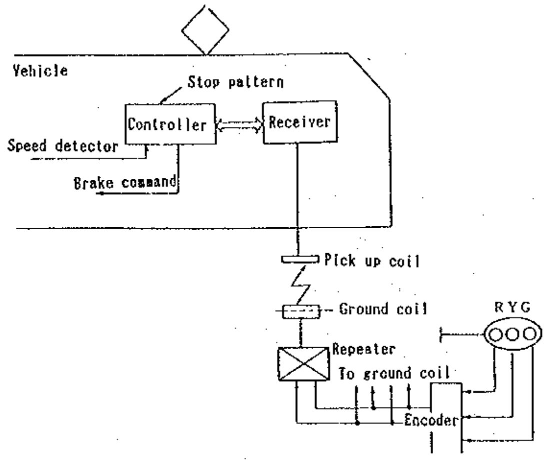


Fig. 1.6.16 ATS-P Type System Block Diagram

the stop signal and compares it with the current running speed. If it is close to that pattern, an approach warning is output, and if a driver does not decelerate after a warning is output, the maximum normal brake functions according to the speed pattern to stop the train. In the case of a block signal, supposing a signal failure occurs, a train is stopped once, then a non-blocking operation with a speed of less than 20 km/h becomes possible. Fig. 1.6.17 shows the principle of the speed control system.

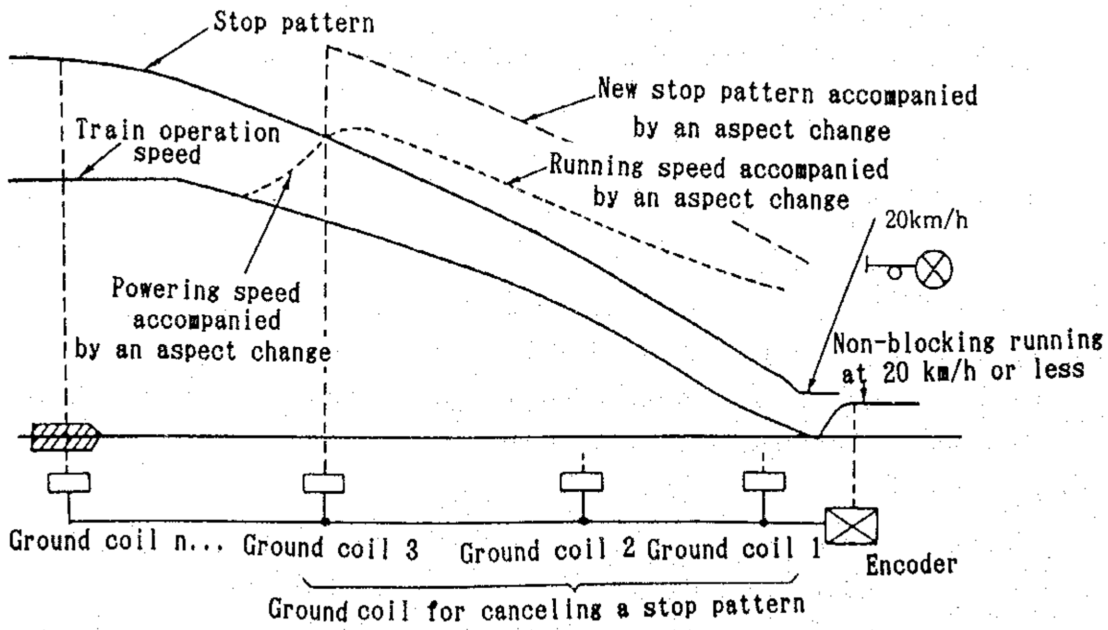


Fig. 1.6.17 Speed Control System

In the commuter section to be electrified frequency of train operation is high and various types of trains including high-speed trains such as expresses, low-speed trains with a long braking distance such as freight trains, commuter trains with large acceleration and deceleration, etc. run at the same time. For this reason, it is suggested that the ATS-P type be adopted.

(a) Telecommunication equipment

a) Train radio system

The conventional train operation is based on a system where a train despatcher and crew members are interconnected indirectly through a despatcher telephone and a station master.

By introducing a train radio system, the train operation system will be more efficient, stable and safe transport will be secured and passenger service will be improved.

i) More efficient train operation system

Train operation requires much manpower. However, not only station staff but also crew can be reduced by introducing the train radio system because then only a driver can operate a train. Communication to the despatcher in an abnormal condition becomes possible through the train radio system, and instructions can be given directly from the despatcher to a crew member.

ii) Securing safe and stable transportat

In the case of high-density train operation when an accident occurs, it is necessary to make an arrangement to protect trains as well as contact the despatcher, etc. Therefore, when an accident occurs halfway between stations, a crew member has to run to a telephone along the railway to contact the despatcher, etc. However, through the train radio system the crew can make contact at an early stage and additional accidents can be prevented or train delays can be minimized. In addition, the train radio system has a positive effect on stable transport. For example, if a crew member finds a disaster along the line or a failure of ground facilities, an accident can be prevented by promptly contacting relevant trains.

iii) Improvement in passenger service

When a train schedule is disturbed due to an accident, if the despatcher gives correct information to the train crew through the train radio system, proper information can be provided for passengers. Furthermore, if a person falls ill, a proper action can be taken by contacting the despatcher or the nearest station, which will contribute to improvement of passenger service.

In this project the train radio system will be introduced only in the commuter sections which are high-density transportation sections.

i) System composition

A train radio system is composed of a control center, approach circuit, broadcast station, vehicular radio equipment, transceiver, etc. as shown in Fig. 1.6.18. The control center is installed in the CTC center or despatcher center and is connected to each broadcast station within the jurisdiction through the approach circuit of an optical cable. Communication is also possible between trains and a base station installed in a station yard by VHF radio wave. A conductor can talk with a driver and a stationmaster of the nearest station through his transceiver by simplex communication mode. The following is a brief explanation of the radio equipment. The interval between broadcast stations is 10 - 15 km, and radio wave output is 10 - 25 W and its power adjustment is made according to intervals of broadcast stations. The frequency is VHF band (150 MHz), possessed by SRT. Of course, adjacent and neighboring stations use different frequencies from each other to avoid interference. The vehicular radio equipment has an output of 5 - 10 W and is adjustable. Transceivers have an output of 1 W and a frequency of 150 MHz and are of a press-to-talk type. Four broadcast stations in the Southern Line, 5 stations in the Eastern Line, 5 stations in the Northern Line, and 2 stations in the Maeklong Line will cover all the commuter sections.

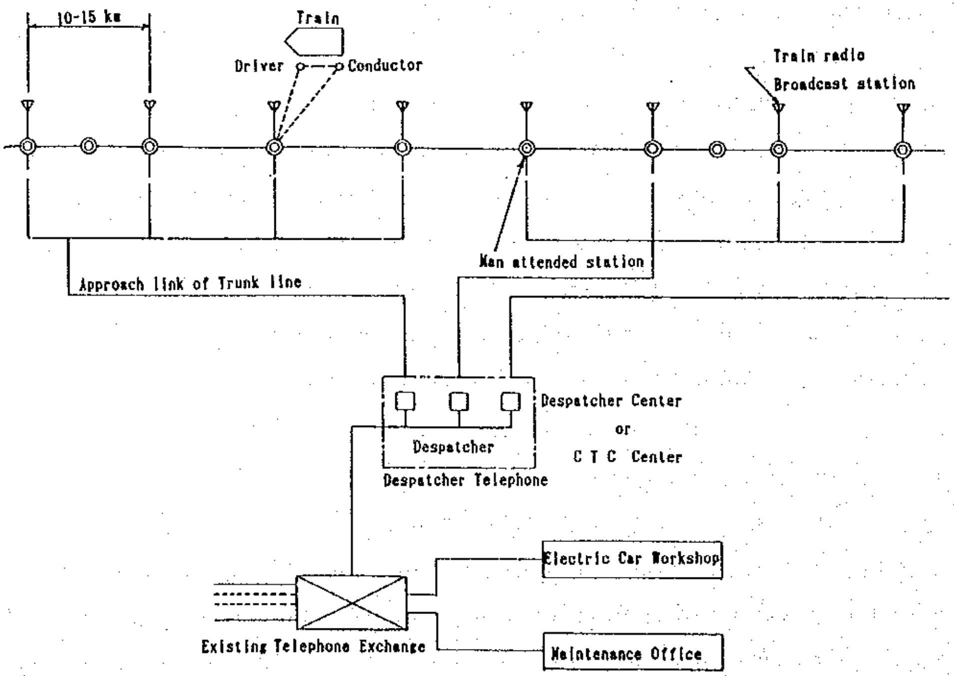


Fig. 1.6.18 Train Radio System

ii) Communication mode

As shown in Fig. 1.6.19, the talking range is as follows. Furthermore, communication with public subscriber telephones is possible through the existing PBX by the operation of the control center.

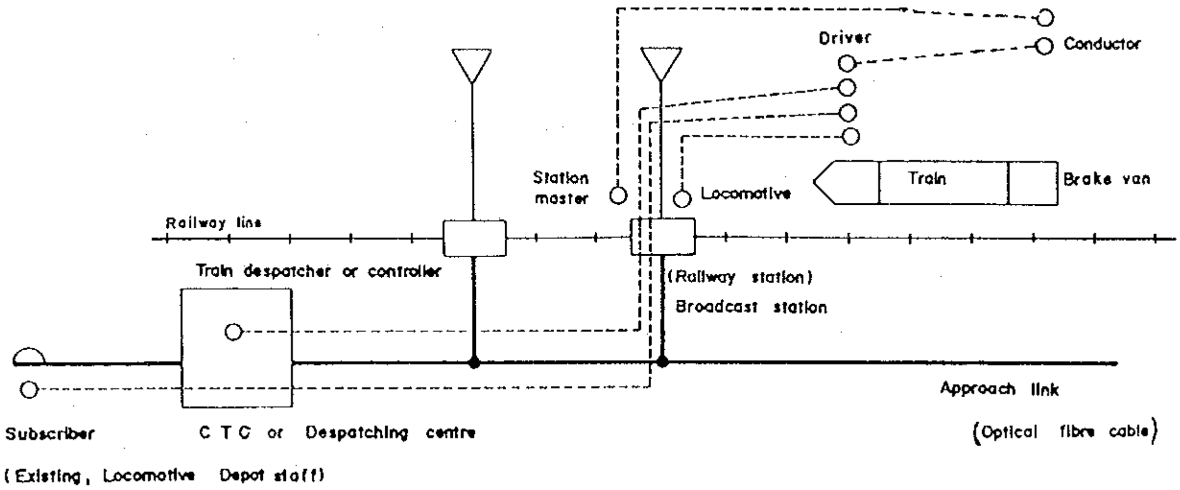


Fig. 1.6.19 Origin-and-destination

(4) Rolling Stock

1) Rolling stock for each service

Railway transport service should be fast, reliable, safe and comfortable.

(a) Commuter service

Mass transport service for commuters needs highly efficient comfortable air-conditioned electric railcars. High acceleration/deceleration and a safety system with ATS and a train-radio are also necessary.

(b) Intercity express service

Regional transport service needs highly efficient comfortable air-conditioned diesel railcars. High speed, a safety system with ATS and a train-radio are also necessary.

2) Rolling stock requirement

(a) Commuter service

a) High acceleration/deceleration

VVVF controller
Electric command regenerative brake (Combined with air brake)

b) High speed

Max. speed ----- 120 km/h

c) Safety system

ATS (Automatic Train Stop)
Train-radio (Space radio)

d) Comfortability

Air-conditioning
Seat (Long-seat)
Number of doors (4 doors: The total of entrance doors at each side wall)
Display of station in the train
Broadcasting system in the train

(b) Regional service

a) High speed

Max. speed ----- 120 km/h

b) Safety system

ATS (Automatic Train Stop)
Train-radio (Space radio)

c) Comfortability

Air-condition
Seat (Box-seat, reclining seat)
Number of doors (2 doors : The total of entrance doors at each side wall)
Display of station in the train
Broadcasting system in the train
Toilet
Public telephone

3) Condition of track and platform

a) Rail gauge : 1,000 mm

b) Height of platform : 800 mm (Commuter section for electric railcars and others)

200 mm (Except commuter section)

c) Max. axle load : 15 tons

4) Voltage of trolley wire AC. 25 KV, Single-phase, 50 Hz

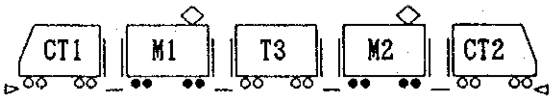
5) Principal specification of electric railcars

a) Type of car : Unpainted light stainless steel body

b) Train formation :

4-car composition (2M2T)

5-car composition (2M3T)



Remarks ◇--- Pantograph | --- Gangway sliding door

▷--- Tight lock coupler (with electric coupler)

● --- Driving wheel ---- Semi-permanent type coupler

c) Track gauge : 1,000 mm

d) Electric power supply : AC. 25 KV, Single phase, 50Hz

e) Principal dimension :

Max. dimension --- 22,700 (Length between couplings) × 2,800 (Width) × 4,145 (Height)

(Height : When pantograph is folded)

Height of floor --- 1,100 mm (Step height of side door is 950 mm)

Distance between bogie centers --- 16 m

Wheel base --- 2.1 m

f) Number of doors : 4 (The total of entrance doors at each side wall is 4)

g) Seat : Long-seat

h) Passenger capacity : Head car 150 (Standing 96, Seating 54)

Middle car 166 (Standing 102, Seating 64)

i) Performance : Acceleration --- 3.3 km/h/sec

Deceleration --- 3.5 km/h/sec (Service)

4.5 km/h/sec (Emergency)

Max. operating speed --- 120 Km/h

j) Bogie	: Bolster-less air spring bogie, with unit type foundation brake rigging
k) Traction motor	: 180 kw × 4, 3 phase asynchronous motor
l) Control system	: VVVF inverter control (With regenerative brake)
m) Brake system	: Electric command regenerative brake (Combined with pneumatic brake) AC motor drive compressor
n) Auxiliary power source	: Static inverter Alkaline battery
o) Door engine	: Single cylinder double acting door engine Belt linked dual motion mechanism Width of the door opening -- 1,300 mm
p) Lighting equipment	: Interior light --- AC fluorescent light (40W) and DC inverter fluorescent light for emergencies (40W) Head light --- Sealed beam (150W/150W) Tail light, car side pilot lamp for door close indication and emergency warning --- LED
q) Ventilation	: 8 cm line flow fan
r) Air conditioner	: 42,000 Kcal/car
s) Safety system	: ATS-P Train radio --- Space radio
t) Display of destination	: Automatic package setting by display setter
u) Display of station	: Automatic character display with LED (With ringing of chime at door operation)

v) TIS (Monitor) : Rolling stock operation information control equipment

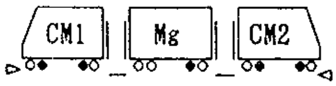
Integrating trouble monitoring and onboard inspection function

6) Principal specification of diesel railcars

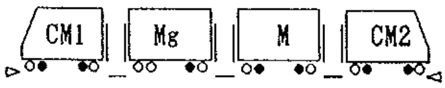
a) Type of car : Unpainted light stainless steel body

b) Train formation :

3-car composition

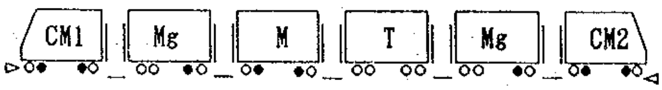


4-car composition

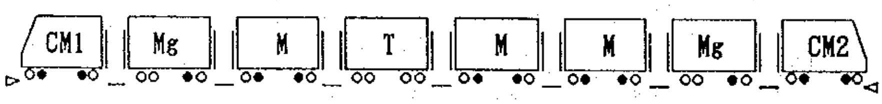


5-car composition

6-car composition



8-car composition



Remarks | --- Gangway sliding door

▷ --- Tight lock coupler (with electric coupler)

• --- Driving wheel — --- Semi-permanent type coupler

c) Track gauge : 1,000 mm

d) Principal dimensions :

Max. dimension --- 22,700 (Length between couplings) × 2,800 (Width) × 3,785 (Height)

Distance between bogie centers --- 16 m

Wheel base --- 2.1 m

e) Number of doors : 2 (The total of entrance doors at each side wall is 2)

f) Seat : Box-seat, reclining seat

g) Passenger capacity : Head car 56 (Seating)

Middle car 64 (Seating)

h) Performance : Acceleration --- 3.0 km/h/sec

Deceleration --- 3.5 km/h/sec (Service)

4.5 km/h/sec (Emergency)

Max. operating speed --- 120 km/h

i) Bogie : Bolster-less air spring bogie, with unit type foundation brake rigging

j) Diesel engine : 420 PS × 2 (420 PS × 1)

k) Brake system : Pneumatic brake

l) Lighting equipment : Interior light --- AC. fluorescent light (40W) and DC. inverter fluorescent light for emergency (40W)

Head light --- Sealed beam (150W/150W)

Tail light, car side pilot lamp for door close indication and emergency warning--- LED

m) Ventilation : 8 cm line flow fan

n) Air conditioner : 42,000 Kcal/car

o) Safety system : ATS-P

Train radio --- Space radio

p) Display of destination : Automatic package setting by display setter

q) Toilet : Toilet is provided

r) Public telephone : Public telephone is provided

7) Railcar procurement plan

a) Commuter service (VVVF EC)

The number of electric railcars for commuter service is estimated based on the demand forecast and transport plan, shown in Table 1.6.9.

Table 1.6.9 Number of Electric Railcars

Year	2000	2005	2010
Eastern Line	44 (4C×11T)	80(4C×20T) (+ 36)	120(4C×30T) (+ 40)
Northern Line	80 (4C×20T)	144(4C× 6T) (+ 64)	205(5C×41T) (+ 61)
Southern Line	0	36(4C× 9T) (+ 36)	92(4C×23T) (+ 56)
Maeklong Line	0	48(4C× 2T) (+ 48)	65(5C×13T) (+ 17)
Reserve (Depot & Workshop)	16 (4C× 4T)	24(4C× 6T) (+ 8)	27(4C× 3T) (+ 3) (5C× 3T)
Total	140 (4C×35T)	332(4C× 3T) (+ 192)	509(4C×56T) (+ 177) (5C×57T)

b) Intercity express service (H-DC)

The number of diesel railcars for intercity express service is estimated based on demand forecast and transport plan, shown in Table 1.6.10.

Table 1.6.10 Number of Diesel Railcars

Year	1997	2000	2005	2010
Eastern Line		(+ 12)	(+ 12)	(+ 4)
Eastern Sea Board	12 (4Cx 3T)	24 (4Cx 6T)	36 (6Cx 6T)	40 (8Cx 5T)
Northern Line	24	45 (+ 21)	60 (+ 15)	65 (+ 5)
Nakhon Sawan	12 (3Cx 4T)	21 (3Cx 7T)	28 (4Cx 7T)	30 (5Cx 6T)
Nakhon Ratchasima	12 (3Cx 4T)	24 (3Cx 8T)	32 (4Cx 8T)	35 (5Cx 7T)
Southern Line	22	33 (+ 11)	44 (+ 11)	56 (+ 12)
Kanchana Buri	6 (3Cx 2T)	12 (3Cx 4T)	16 (4Cx 4T)	20 (5Cx 4T)
Hua Hin	16 (4Cx 4T)	21 (3Cx 7T)	28 (4Cx 7T)	36 (6Cx 6T)
Reserve		(+ 4)	(+ 4)	(+ 2)
(Depot & Workshop)	6 (3Cx 2T)	10 (3Cx 2T) (4Cx 1T)	14 (4Cx 2T) (6Cx 1T)	16(5Cx 2T) (6Cx 1T)
Total		(+ 48)	(+ 42)	(+ 23)
	64(3Cx12T) (4Cx 7T)	112 (3Cx28T) (4Cx 7T)	154 (4Cx28T) (6Cx 7T)	(5Cx19T) 177(6Cx 7T) (8Cx 5T)

8) Example of railcars

Fig. 1.6.20 shows examples of electric railcars for commuter service and diesel railcars for intercity express service.

Electric railcar (for commuter service)

Diesel railcar (for intercity express service)

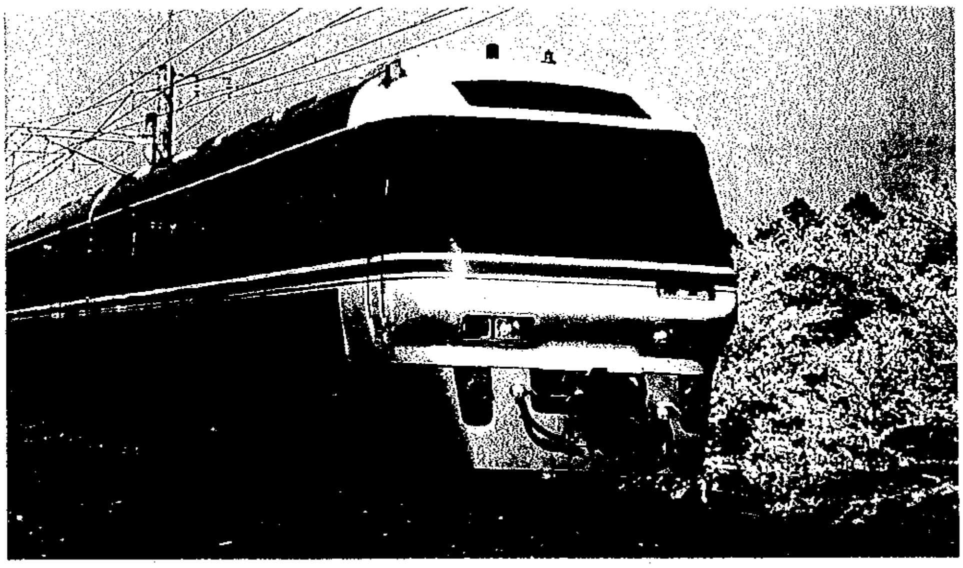


Fig. 1.6.20 Examples of Railcars

1.6.4 Station Plaza

(1) Role and necessary function of station plazas

Unlike the case of cars which convey users from door to door, the function of a railway is to convey passengers from station to station. Therefore, feeder transport (including going on foot) is necessary for the passengers. For this purpose, station plazas are required to fulfill the function of a connecting service to feeder conveyance means.

Usually, facilities required for a station plaza are: (a) a sidewalk, (b) a taxi stand and a taxi pool, (c) a bus berth for passengers to get on/off their buses, and (d) a space for private-car owners to get in/out of their cars.

In addition, (e) a two-wheeled vehicle pool and (f) a private-car pool may be required depending on the functions of the station.

In particular, a bus berth is indispensable for a station plaza to play its role as a public transport means. It must be contrived, therefore, that buses bound for various major spots in the city are extended into the station plaza in order to ensure the passengers' convenient transference to their buses in a short time.

In case feeder public transport means of track systems (such as Sky Train, Thanayong, etc.) are prepared, it goes without saying that connection to such means is required. In this case, rather than to ensure an access through the station plaza, it is important to plan, at the design stage, station structures for both the track systems on the basis of a full consideration of passenger flow.

For example, in Japan, a railway station plaza of a railway is recognized as an indispensable public transport facilities to connect with access means. The station plaza is, therefore, prepared jointly by the local public organization concerned and the relevant railway company. Usually, the competent local public organization decides the area where a station plaza is to be established as a "town/city planning area".

An agreement has been concluded to the following effect between the Ministry of Construction as the authority over divisions in charge of road preparation, etc. of local public organizations and the Ministry of Transport which is the authority over railway companies with regard to the construction and maintenance of station plazas:

i) Station plazas should be decided as "city/town planning areas" in accordance with the provisions of the Town Planning and Zoning Act.

ii) In principle, a railway organization should bear the amount equivalent to one sixth of the costs of land, construction and maintenance of a standard station plaza area calculated based on the estimated number of passengers at the station twenty years later by applying the "calculation formula of the 28th year of Showa". The rest should be borne by the relevant local public organization responsible for the city/town planning.

"Calculation Formula of the 28th Year of Showa"

A: Standard plaza area

B: Number of passengers to use the station

In the case of a station for commuters:

$A = 0.119B \quad (B \leq 73{,}000)$

$A = 0.0259B + 25.09\sqrt{B} \quad (B > 73{,}000)$

In the case of a local station:

$A = 0.238B + 9.85\sqrt{B} \quad (B \leq 30{,}000)$

$A = 51.65\sqrt{B} \quad (B > 30{,}000)$

Remarks: the 28th year of Showa = 1953

As traffic conditions have changed considerably from the 28th year of Showa (1953), at present in most cases the calculation is applied only to decide the amount that the railway side should bear and actually larger station plazas are provided with more than five sixth of the cost borne by the relevant local public organization.

(2) Examples of station plazas

Fig. 1.6.21 shows the example of a station plaza for Honhachinohe Station, with 7,721 passengers/day, the northern plaza of 2,650 m^2 and the southern plaza of 950 m^2. This plaza was planned in 1972 for the case of a local station with an estimated 11,000 passengers. The railway track was elevated on the second story and the station business is operated on the first floor under the track.

For 11,000 passengers, the necessary area of the plaza is approximately 3,600m^2. In accordance with the agreement between the Ministry of Transport and the Ministry of Construction, the Railway offered 900m^2 of land in the station plaza area that is equivalent to a quarter of the necessary land for the station plaza. Other land was purchased by the local government as the road administrator. After the land acquisition, the dividing line of land possession was decided parallel to the railway line without changing the area (size of land) passessed. So the Railway got to possess a quarter of the land on the station side. The construction cost of earthwork or pavement and the maintenance cost of cleaning or patching are separated by this dividing line of land possession and each sector bears the cost of construction and maintenance concerning owned land. Recently on account of railway privatization, this cost sharing agreement was changed so that private railway companies to bear one sixth instead of one fourth.

There are 2 bus stops in front of the station and 31 bus routes are provided. There are also 3 taxi stops and 16 taxi parking spots. Under the viaduct adjacent to the station, a free parking area for bicycles, managed by the local government ,is provided.

Fig. 1.6.22 shows an example of improvement. For the bus stop, several berths are provided to distinguish stopping positions by their destinations.

Arrangements must be made so that all buses passing through the adjacent roads can stop off at the bus stop located in the plaza in front of the station. In addition, a taxi and tuktuk stop and a pool must be provided beside a station. All these facilities must be placed under the stationmaster's control.

Stickers to permit taxis and tuktuk to enter the station plaza should be issued by the railway and a registration fee must be collected. Following the example of a public taxis in the Bangkok Airport, taxis other than meter taxis must determine a fixed fare by destination so that every passenger can utilize them without anxiety.

A bus stop and a taxi stop are indispensable at each station for passengers who need transport means from a station to their destinations. These facilities must be installed at a place not far from the entrance and exit of the station. In addition to these facilities, a vehicle standby space with a required capacity must be provided in the plaza. Furthermore, it is desirable to secure a parking lot for privately-owned vehicles near the station. In particular, buses on regular routes are a complement to railway service as public transport means connecting with each other, so that bus routes passing a station plaza should be sufficient to go to various spots in the city.

It is indispensable to secure daily available access transport means in order to use a railway for commuting to school or to work. If a distance from a station to a destination is 500m or less, priority is given to walking to the destination so that it is necessary to improve facilities for pedestrians. It is desirable to build a sidewalk wide enough for pedestrians and install a roof over the sidewalk as pedestrian facilities.

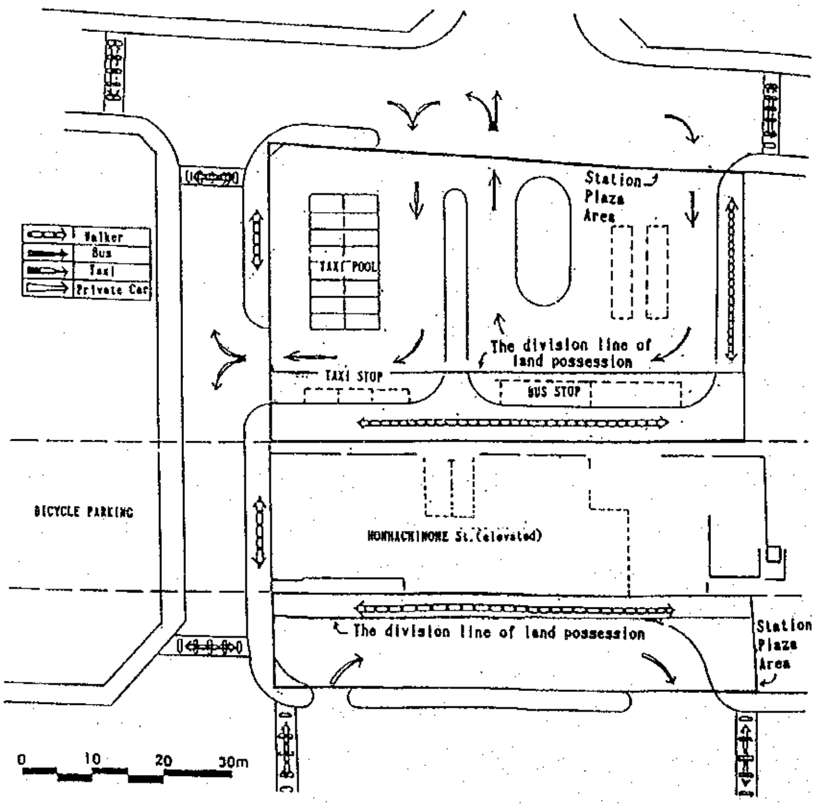
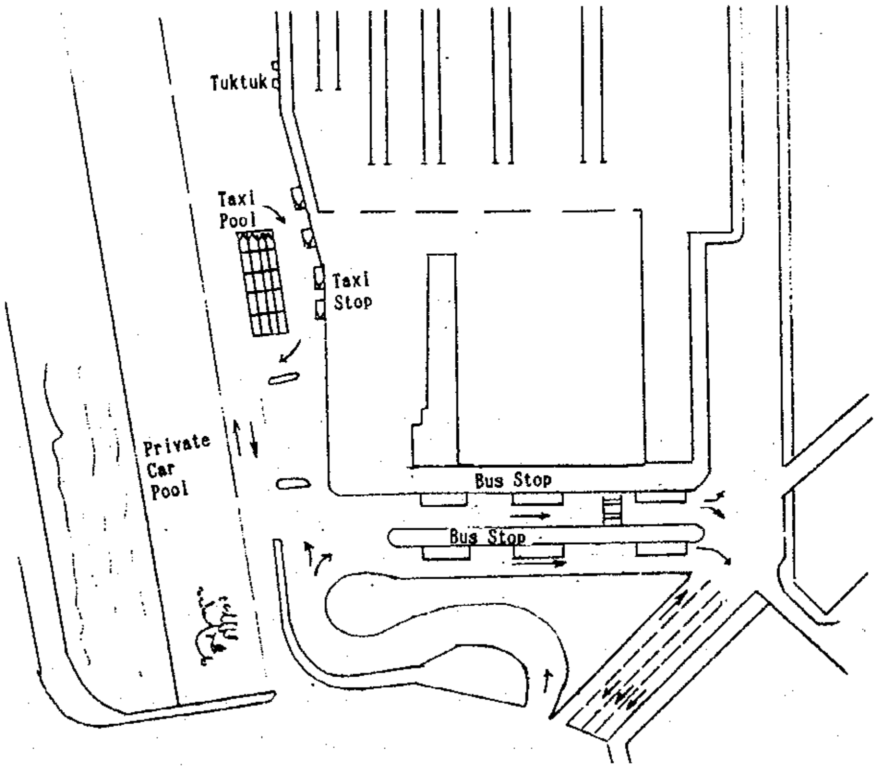


Fig. 1.6.21 Station Plaza of Honhachinohe



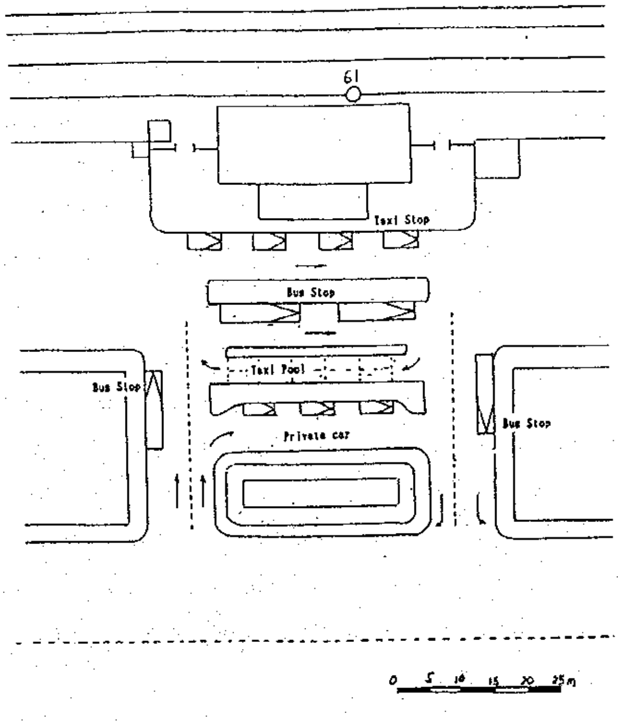


Fig 1.6.22 Examples of Improvement

1.6.5 Connections with Bangkok Mass Rapid Transit Projects

Mass rapid transit systems have two functions as an urban transport system. One is to connect the center of the city with the outskirts through radial lines. The other is to cope with various flows of people within the center of the city as well as to connect radial lines with various spots in the center of the city (generally within a 15 km radius). Sections of radial lines in the center of the city are also regarded as a part of the network of the latter.

SRT's lines consist of radial lines and are forming a network in the center of the city by organically combining the lines of the Hopewell Project, but SRT's lines itself have only major stations where express and rapid trains stop. These stations can be used to transfer conveniently in up-and-down movement to the lines of the Hopewell Project which is expected to be a distributor in directions along SRT's lines. In relation to mass rapid transit projects in Bangkok, the Hopewell Project mentioned above and other projects such as the BMA Tanayong Project and the MRTA Sky Train Project are planned. A subway project has been announced together with its proposed routes, but the entire project including these routes has not been determined yet. (Cf. Fig. 1.3.2)

When the SRT provides full scale commuter service through its four radial lines, unless the mass rapid transit systems including the Hopewell Project are completed to give access to offices, commercial centers, etc. in the center of the city, commuters will be forced to be dependent on buses in crowded roads for access/egress, which will reduce the effect of SRT's measures. For the Southern Line and the Maeklong Line which do not reach the center obstructed by the Chao Phraya River, the Hopewell Project second phase which will connect them with the Eastern Line and Northern Line respectively across the river is indispensable.

In relation to mass rapid transit systems under concrete plans besides the Hopewell Project lines, only Bang Sue and Hua Lamphong stations of the Sky Train Project will connect to SRT's stations. The Sky Train line will cross near Asok Station and the Tanayong Project line crosses near Phayathai Station of the Hopewell Project commuter service. The detailed plans of stations located near these crossing points have not been formulated yet, and it is necessary to discuss these plans in accordance with the progress of the projects to enable passengers to transfer smoothly.

In planning subways expected to be constructed and the second phase of the projects mentioned above, it is also necessary for the SRT's lines to take measures to make convenient connections directly or through the Hopewell Project's commuter service.

It is necessary to make connections with buses as substitutes for connections with mass rapid transit systems. Since it is expected to take a long time to complete the entire mass rapid transit network, passengers will be forced to be dependent on buses to make connections with railway lines until then. It is much more convenient to combine the use of a radial railway line with the shortest bus access/egress to/from the nearest station compared with the use of cars stuck for a long time in crowded roads in the Bangkok Metropolis with heavy traffic. Although the number of trips from/to the center of the city does not change, changes in the length of trips and the routes of trips can ease the congestion on the roads. In the center of the city, it is satisfactory to locate bus routes passing adjacent to stations instead of establishing bus terminals in front of stations where it is difficult to obtain land for them. It is essential to reorganize the bus route network based on a bus-railway-combination transport system providing bus terminals near stations in the suburban area.

It is necessary to consider the design of Hopewell commuter stations so as to have connections with crossing trunk roads. (Elevated mass transit systems and subway lines are also expected to run along trunk roads).

The organizations, which will be in charge of carrying out the above-mentioned projects, are shown below.

(a) Hopewell Project

This project will be carried out based on the Concessional Agreement concluded by the Ministry of Transport and Communication and the SRT and Hopewell (Thailand) Co., Ltd., which came into effect on December 6, 1991 with regard to the "railway transport system, elevated road system and SRT land development". The project is to convert some parts of SRT's four railway lines into elevated lines with a total length of about 50km and to construct community railway lines (a mass rapid transit system of north-south alignment line with a length of 34.2km and east-west alignment line with a length of 25.9km) along these elevated railway lines as well as six lane elevated roads, and to connect Hua Lamphong with Won Wien Yai and the Eastern Line with Thon Buri, which are separated by the Chao Phraya River, in exchange for the right to develop SRT's land located on the right-of-ways and at Hua Lamphong, Bang Sue, Makkasan and other places. This project will be carried out in the 30-year-term BOT method.

Urban-type stations including newly-constructed ones will be set up at short intervals in the Hopewell commuter lines. SRT's stations will be provided only at major spots. Since both lines are expected to be organically connected with each other, they will virtually become four-track (five-track) lines. Hopewell commuter train stations connected with the remaining SRT stations have been planned to be located above and below to enable passengers to transfer to other lines easily.

With the project, it has been planned to shift the Bangkok central station for trunk line passenger service from Hua Lamphong to Ban Sue, while the final size of Hua Lamphong Station and its passenger car depot has not been determined yet, but it has been planned to greatly decrease their size. In the first stage of the project, a part of the project in the Northern Line and the Eastern Line have been planned to be constructed. Piling work (by cast-in-place piles with a large diameter) between Ban Sue and Don Muang has already started, but a lot of detailed matters on the project remain undecided. The time of the project's completion has not been announced yet. The project seems likely to be completed after the middle of 1997 at the earliest.

(b) BMA Tanayong Project

The project will be carried out by the BMA on a BOT system contracted with the Tanayong Group. The project is to construct elevated LRT lines consisting of an east-west line with a length of 8.5km above Sukhumvit Road connecting the center of Bangkok with its eastern part as a trunk road and a south-north line with a length of about 10km above Siliom Road regarded as one of the bustling streets and Phahonyothin Road connecting the center of the city with its northern part as a trunk road.

Since the depot which at first was planned to be located at Lumphini Park met with opposition, its site could not be determined. Recently it has been decided to use the north bus terminal for the depot, and construction work has been started.

Since one of the lines is to run above Phahonyothin Road, this line can be connected with SRT's Eastern Line near Phahonyothin Station of the Hopewell commuter service. It is desirable to extend the line in the western direction and connect the line with the Northern Line (Hopewell commuter service) in the future.

(c) MRTA Sky Train Project

This was once an ETA (Expressway and Rapid Transit Authority of Thailand) project called the "Sky Train project", but the project has not yet been carried out. The MRTA (Metropolitan Rapid Transit Authority) was established to take over this project. Its route was reviewed. The depot site which was determined and prepared before will be used. Based on the revised route, the execution of the project is now at the starting line.

(d) Connections between these three projects

As shown in Fig. 1.3.2, SRT-Hopewell, Tanayong and MRTA's routes have been determined. If these projects are carefully planned to enable passengers to smoothly transfer to other lines at stations located at or near crossing points, these projects will provide a considerably well organized as the mass rapid transit network in the first stage.

(e) SRT's urgent plan

The time of the projects' completion has not been disclosed yet. They do not seem likely to be completed before the middle of 1997. The SRT can be said to be the only mass rapid transit system in Bangkok until then. It is, therefore, important to settle on an urgent plan for SRT's commuter service as well as SRT's long-term development.

1.6.6 Management and Maintenance

(1) Maintenance of track and structure

The track extension length to be maintained will be doubled after track-doubling. Furthermore, with increase of speed and passing tonnage due to the increase of train services, the required amount of track maintenance will more than double. In order to cope with this situation, the track must be reinforced (making rails heavier, making sleepers PC and increasing ballast thickness) and labor must be saved by introducing appropriate maintenance machinery. At the same time, it is necessary to improve efficiency. Taking the present supply and demand of workers into consideration, it seems to be appropriate to cope with this situation by increasing maintenance personnel equivalent to the increase in the amount of necessary track maintenance, but judging from the experience of the Japanese National Railways this approach may have a negative result in the future. As the national economy develops, mechanization will advance and production power per capita will improve, so that the productivity of the railway employees must be increased. Otherwise, the SRT cannot pay an average salary to the employees, or, if it does, must be prepared for a large operating deficit. Once a person is employed, the enterprise is a responsibile for them for about 40 years. In the event of an increase of business operations, it is wise to carry forward streamlining and labor-savings taking into account the labor situation 10 or 20 years later. Consequently, in making a transport capacity build-up plan, it is important not only to reinforce and improve facilities (ncluding track) and introduce maintenance machinery but also not to increase maintenance personnel. In a double-track section, a multiple tie tamper is to be equipped for every track extension of approx. 50 km and an intensive compacting is to be executed.

(2) Maintenance of electric facilities

As far as maintenance of signalling and telecommunication facilities is concerned, there is no substantial difference between the facilities at the time when this project is started and those after completion of the project, although these signalling and telecommunication facilities themselves become sophisticated.

The maintenance system when the project is started need not be changed because there is little change in the quantity of the facilities. Here, only the maintenance system of electrification facilities is described.

(a) General

Electrification facilities consist of catenaries, substations, subsection posts, AT posts, transmission lines and remote control facilities. It is considered that preventive maintenance needs to be provided to traction substations and catenaries which directly affect operation of trains, but only corrective maintenance will be sufficient for the other facilities. Corrective maintenance should be adopted for facilities as much as possible and work safety and labor saving should be promoted by making the most of machinery and mobility.

An asset of a transmission line from electric power companies to traction substations must be transferred to the electric power company after completion of the work, and the electric power company must provide maintenance services.

Notes:

- "Preventive maintenance" means that equipment functions are kept to their originally stable condition before the equipment malfunctions.
- "Corrective maintenance" means that equipment malfunctions are repaired to their original condition after the equipment malfunctions.

(b) Scope of maintenance

Electrification facilities are dispersed along the railway track. It is desirable that maintenance depots are dispersed in order to shorten the time required to arrive at the work site for maintenance or recovery of an accident. However, it is disadvantageous to disperse them too much in terms of cost and staff management. Therefore, it is advisable that the maintenance depot should be located at Bang Sue at the center to take charge of maintenance of the lines. A different technical group must be set up for a traction substation maintenance because it is different in technology from catenaries.

(c) Maintenance staff

Each group consists of a chief inspector, an assistant inspector, artisans, semi-skilled workers and unskilled workers.

Four power despatchers will be assigned to the Bang Suc remote control center for monitoring and control. The following table shows staff requirements for the maintenance section and remote control center.

Table 1.6.11 Staff Requirement for the Maintenance Sections and Remote Control Center

Item	Substation remote cont. equip.	Overhead equipment	Total
Power despatcher	4		4
Chief inspecter	1	2	3
Assistant inspecter	1	2	3
Artisan	2	8	10
Semi-skilled worker	2	6	8
Unskilled worker		10	10
Total	10	28	38

It will be very efficient to transfer the staff members above to a subcontractor during the construction period so that while engaged in construction work they can acquire valuable experience to take back with them. The staff members for maintenance must be obtained from similar workshops such as a rolling stock plants and electric facilities sections, and if sufficient staff members cannot be obtained, applicants for this post must be recruited and employed by public advertisement.

(d) Education and training

Electrification of a railway is an integrated system of technology of various fields such as civil engineering, rolling stock, electricity operation, etc. It is a cornerstone of success to put energy into transfer of technology and expertise in planning, designing, execution and maintenance obtained from experts.

In addition, it is necessary to give high-level training to those who are engaged in education through a training program including an overseas training program.

Generally speaking, since the recent electrification facilities are very reliable, there is little chance to practically operate the facilities. On the other hand, if a failure occurs, a prompt recovery is required. Therefore, it is necessary to repeatedly train the maintenance staff in technology at all times.

It is important to periodically give technical training to the maintenance staff by using a simulation training panel combined with a spare substation machine and a simulation stringing of catenary facilities.

In addition, it is quite natural that an extensive public relations compaign is necessary in order to make the general public understand that a 25 KV extra high-tension electric wire is dangerous and they should look out for their own safety.

(e) Maintenance cost difference

As for facilities for telecommunications, aerial open wires will be replaced mainly with optical fiber or underground cables. Since optical fiber and underground cables are maintenance-free, minimum maintenance staff and costs are required. Maintenance of the existing aerial open wires such as repair work on wire disconnections, insulator damage, deterioration of insulation, crosstalk and cutting of trees interfering with the wires along a railway line requires a great deal of labor and expense. Therefore, as far as the telecommunications are concerned, this project will considerably reduce personnel cost and expenses.

On the other hand, as for the signalling, this project will modernize the facilities and also reduce the personnel cost and labor. However, the number of facilities such as track circuits, signals and ATS's will greatly increase, which leads to an increase in maintenance cost and personnel.

As a result, as far as the signalling and telecommunications are concerned, the difference of the maintenance cost will be zero because an increase in the cost of signaling will offset the decrease in the cost of telecommunications. As for the electrification facilities, the maintenance cost is a new increase because new facilities will be constructed where no facilities exist.

(3) Rolling stock

(a) Type of inspection Draft)

Type of inspection are listed in Table 1.6.12.

Table 1.6.12 Type of Inspection

Type of inspection	Inspection periodicity	Inspection facilities	Contents of inspection
Daily	Within 72 hours	Depot	Function inspection of a car inspection and renewal of parts
Monthly	Within 3 months	Depot	Function inspection of main equipment
Intermediary	Within 3 years	Workshop	Demounting and inspection of main equipment
Overall	Within 6 years	Workshop	Overhaul inspection

(b) Main facilities of workshop and depot

Main facilities of a workshop and a depot are listed in Tables 1.6.13 and 1.6.14.

Table 1.6.13 Main Facilities of a Workshop

Shop	Main facilities
Administrative buildings	Office, Dressing room, Dining room, Bath room, Washing room, etc.
Incidental buildings	Garage, Storage, etc.
Energy center	Boiler, Air compressor, etc.
Entrance/Leaving inspection shop	Air brake tester, Electric car wiring tester, ATS device tester, Dielectric strength tester, Performance tester, Running record tester, Air compressor, Air blast equipment, Scaffolding car roof, etc.

(Continued)

Shop	Main facilities
Bogie shop	Electric welder, etc.
Wheel and axle shop	Oil flushing equipment, Hydraulic wheel press, Wheel and axle traverser, Vertical lathe, Wheel lathe, Magnetic flaw detector, Ultrasonic flaw detector, Axle bearing removing machine, Jib crane, Overhead travelling crane, etc.
Traction motor shop	Lathe, pinion heater, Air blast booth, Axle bearing induction heater, Traverser for rotating machine, Jib crane, overhead travelling crane, etc.
Car-body shop	Electric welder, Demount/Mounting equipment, Scaffolding for car-body repair, etc.
Electric equipment shop	Dust arresting machine, Washing equipment, Dielectric tester, Electromagnetic valve tester, ATS tester, Distributing circuit breaker tester, Relay tester, Main control rectifier tester, Battery capacity tester, Main controller tester, Electric power source device for testing, Various electric measuring apparatuses, Jib crane, Overhead travelling crane, Train-radio tester, etc.
Air brake shop	Air compressor, Washing machine, Dust arresting equipment, Air brake valve tester, Door engine tester, etc.
Machine shop	Lathe, Upright drilling machine, Radial drilling machine, Universal milling machine, Pedestal grinding machine, Hacksawing machine, Axle lathe, Air compressor, Grinding machine, Hydraulic press, Shearing machine, Spot welder, Jib crane, Overhead travelling crane, etc.
Others	Fork lift truck, Motor truck, Shunting loco, etc.

Table 1.6.14 Main Facilities of a Depot

Shop	Main facilities
Administrative buildings	Office, Dressing room, Dining room, Bath room, Wash room, etc.
Incidental buildings	Garage, Storage, etc.
Energy center	Boiler, Air compressor, etc.
Monthly inspection shop	ATS device tester, Performance tester, Air blast equipment, Lifting jack, Jib crane, Scaffolding for car roof, etc.
Daily inspection shop	ATS device tester, Scaffolding for car roof, etc.
Wheel lathe shop	Wheel lathe, etc.
Air blow shop	Air blast equipment, etc.
Signal control shop	Signal controller, etc.
Others	Automatic car cleaner, Scaffolding for car cleaning, ATS tester, Train-radio tester, Fork lift, Motor truck, etc.

(c) Location of workshop and depot for commuter service

Location of a workshop and depots for commuter service is shown in Fig. 1.6.23.

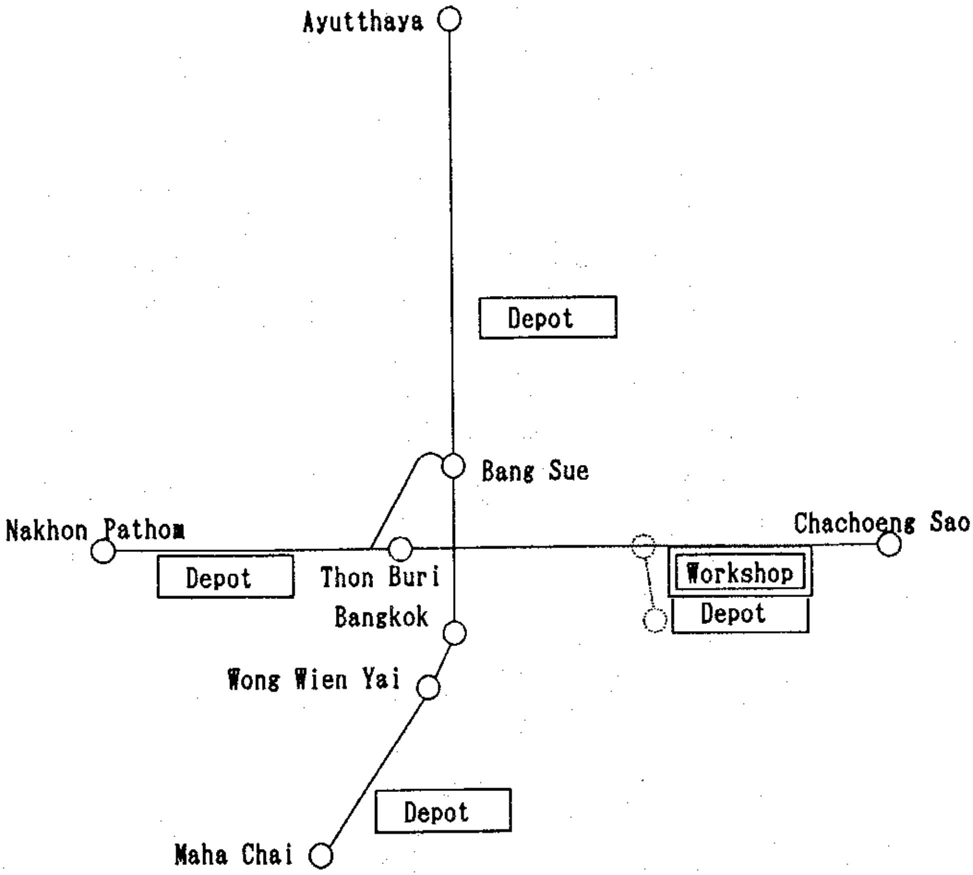


Fig. 1.6.23 Location of Workshop and Depots

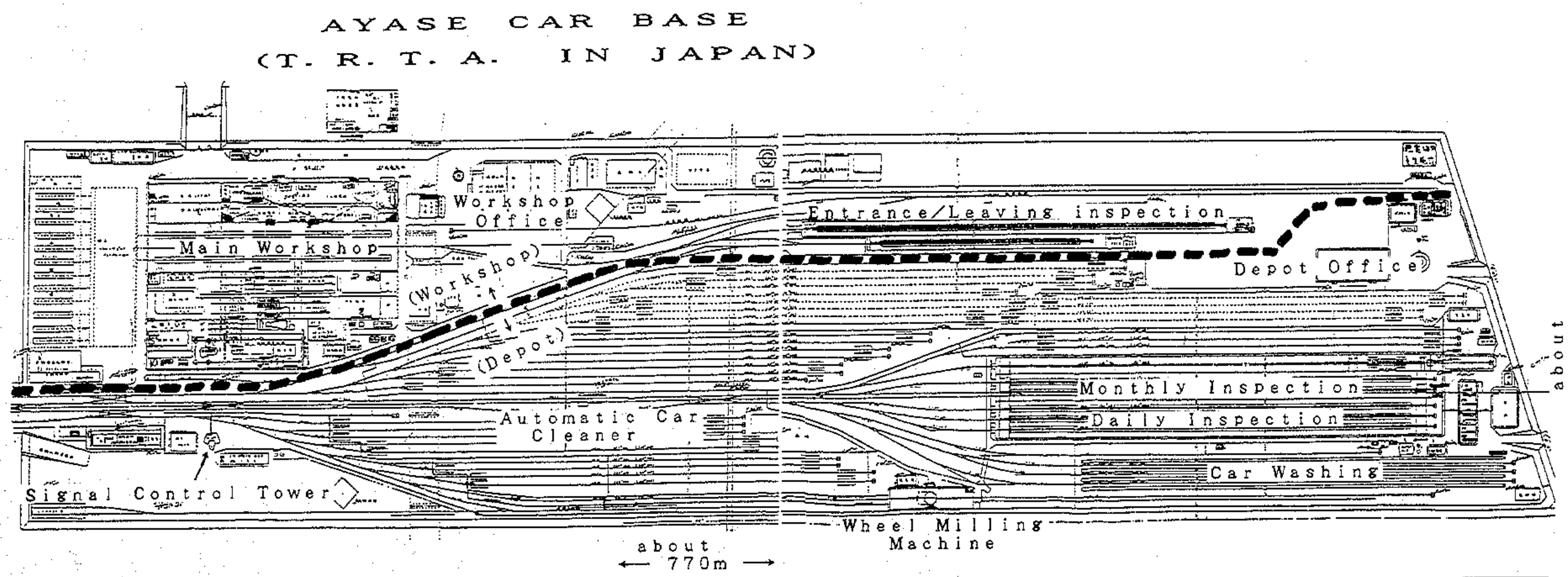
Note :	Workshop (1)	---- Eastern Line (Thon Buri ~ Chachoeng Sao)	1
	Depot (4)	---- Northern Line (Bang Sue ~ Ayutthaya)	1
		Maeklong Line (Wong Wien Yai ~ Maha Chai)	1
		Eastern Line (Thon Buri ~ Chachoengsao)	1
		Southern Line (Thon Buri ~ Nakhon Pathom)	1

(Intercity express service)

For new diesel railcars, the existing workshop and depot are used.

(d) Example of Layout

As an example, Ayase Car Base of TRTA in Japan is shown in Figs. 1.6.24 - 26.



	Ayase Workshop	Ayase Depot
Number of Rolling Stock	729 (Chiyoda Line 369) (Yurakucho Line 360)	369 (Chiyoda Line)
Major Work	Intermediary Inspection (3 years cycle) Overall Inspection (6 years cycle)	Daily Inspection (3 days cycle) Monthly Inspection (3 months cycle)
Number of Employees	187	100
Assigned Line	Chiyoda Line, Yurakucho Line	Chiyoda Line

Fig. 1.6.24 Width and Layout of Car Base (Reference)

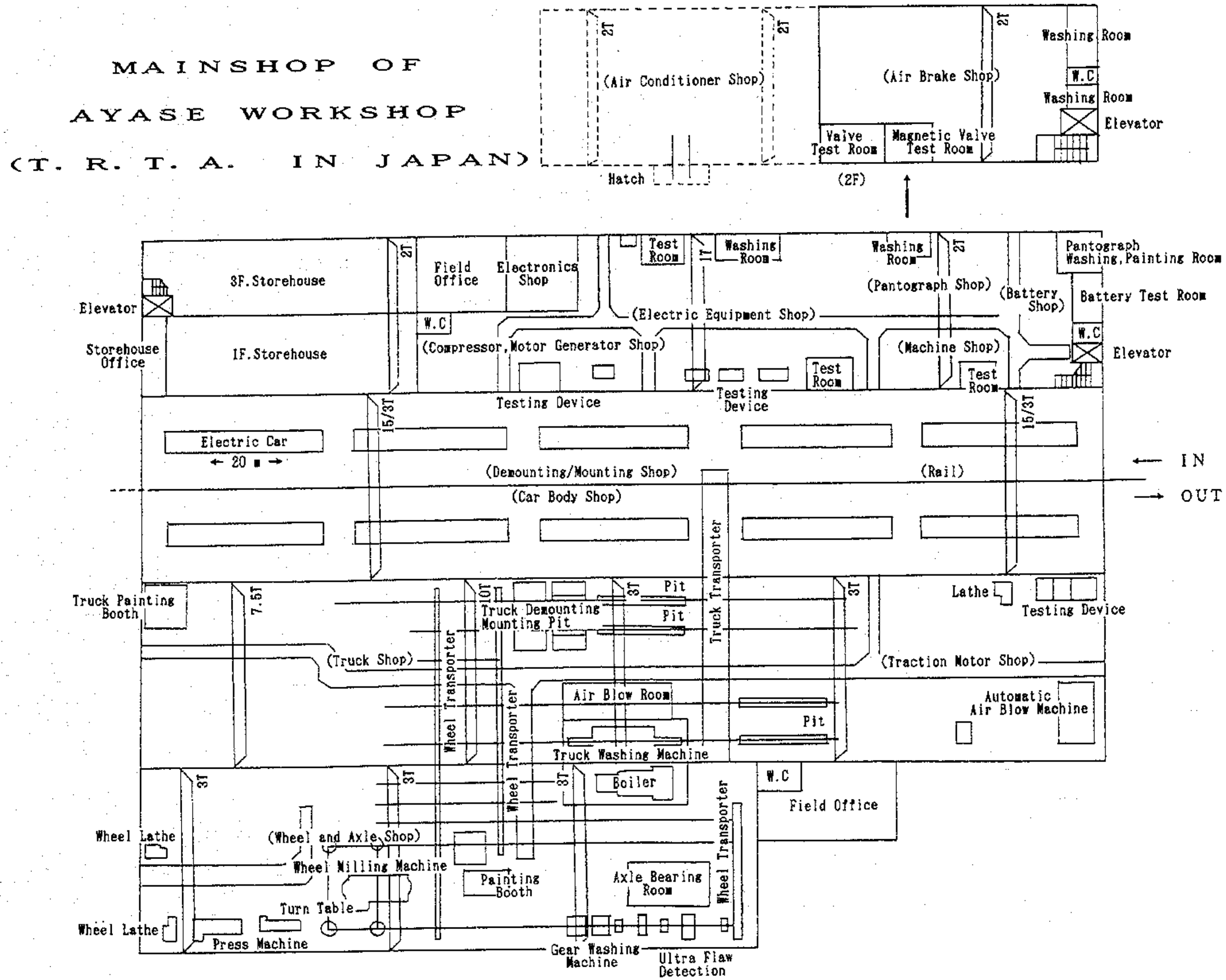


Fig 1.6.25 Layout of Main Shop

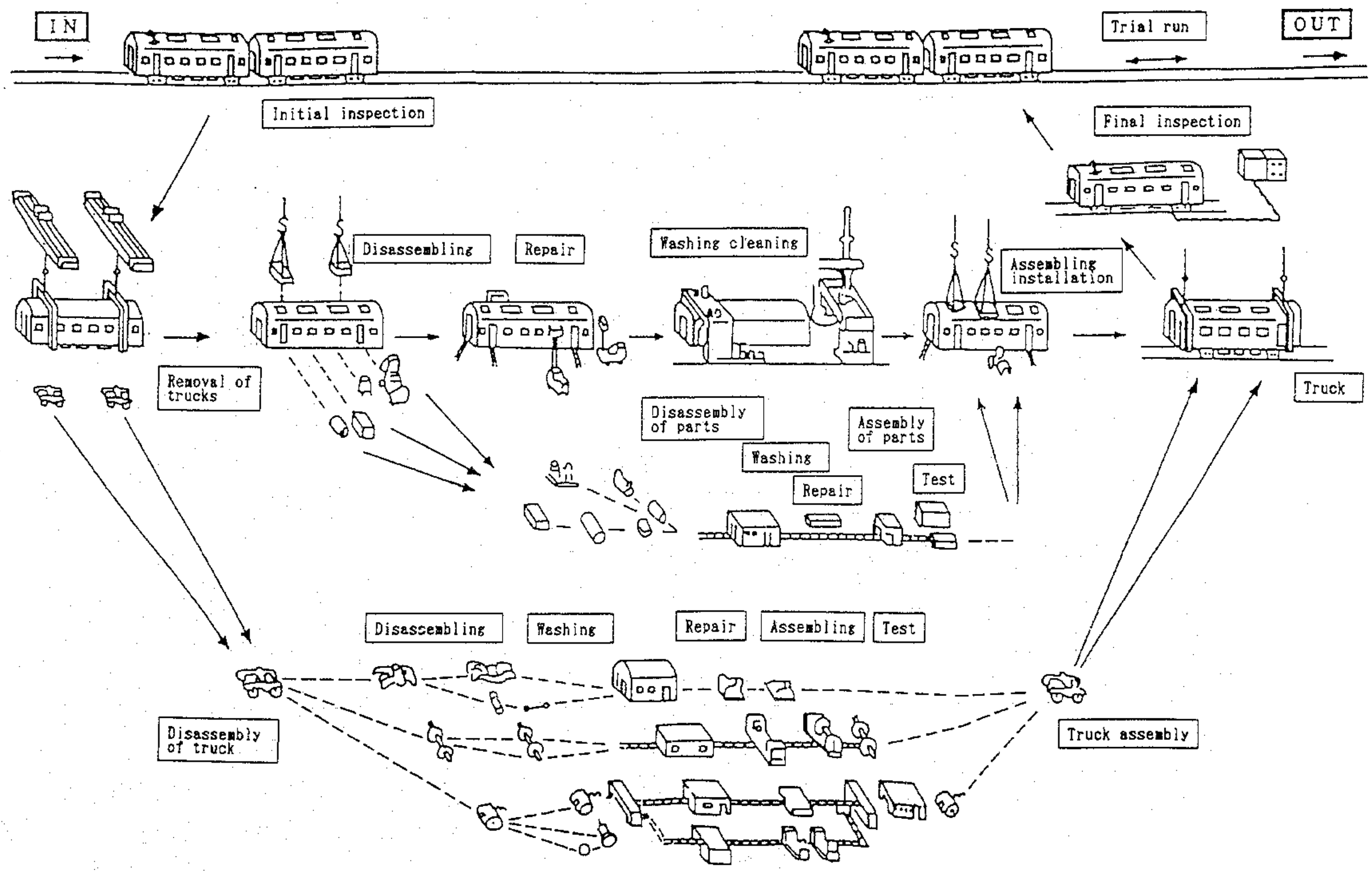


Fig 1.6.26 Flow of Intermediary and Overall Inspection

1.7 Financial Resources for Railway Improvement

1.7.1 Problem of Profitability of Railway Improvement

In many countries of the world many plans have been established concerning the introduction of railways / mass rapid transit systems as measures for dealing with urban transport. However, in spite of the strong need to realize these projects, many of them have not yet started. The biggest reason for this is the problem of profitability, because a project to introduce a railway / mass rapid transit system requires an enormous amount of funds for construction.

It has been confirmed that, especially in comparatively large cities, the increasing transport demand should be dealt with by a railway / mass rapid transit system. Although, with its "space-saving" feature, it is the only possible measure which can deal with the heavy traffic demands in large cities, the funds required are so huge that they cannot be recovered from fare revenues.

In addition, in some cases fares are held down politically and often to an extent that they cannot repay investment costs or cover operation expenses.

Investment cost of a railway / mass rapid transit system is very huge as mentioned above. However, in large scale cities such as the Bangkok Metropolis no, other measures can deal with the vast traffic demand supporting their socio-economic activities. Road transport requires a very large space compared with its capacity. That is to say, there is no alternative but to provide a railway / mass rapid transit system, or give up smooth communication and socio-economic activities.

1.7.2 Securing Funds for Urban Transport

The reasons why railways / mass rapid transit systems in large cities, which are necessary and feasible in view of socio-economy, have problems of profitability are explained as follows.

(a) Invisible benefits

Benefits such as smooth communication and the possibility of commuting are invisible and abstract as if they were air, and rather only provide people with what they feel is an essential right. Therefore, it is difficult to reflect them in fares. Such benefits should be regarded as those which the government obtains. This can be a ground for subsidies from the government.

(b) Reduction of external diseconomies

Benefits which reduce external diseconomics such as air pollution, noise and the global increase of carbon dioxide by automobiles are also impossible to reflect in fares. This also can be a ground for subsidies from the government.

(c) Outflow of benefits (Development gains)

Development such as housing, a commercial complex, overall urban development in an urban area, a suburban area, downtown and an area around a station which can be realized thanks to improvement and reinforcement of a railway / mass rapid transit system can produce huge development gains. However, they usually flow out and can not be utilized for repayment of the investment for the improvement. In many countries, refunding the investment cost by "value capture" has been conceived, tried and executed, and accompanied with this many theoretical studies have been carried out.

(d) Politically influenced fare ceilings

In some cases fares are held down politically. In this case, a clear system of subsidy or compensation by the government is necessary, as a type of PSO (Public service obligation). In the EU, the PSO is clearly stipulated. There are some cases of fare ceilings without any subsidies and compensation, which leave a cumulative deficit leading to ruin.

To examine resources for funds for urban transport, costs and expenses are classified as shown in Table 1.7.1.

Table 1.7.1 Classification of Costs and Expenses of Railway/MRT System Improvement and Operation

Classification	Contents and characteristics
(a) Investment cost of land and infrastructure	Land, viaduct, bridge, mountain tunnel, roadbed, underground tunnel, structure for grade separated crossing with road: These require huge investment cost especially in a urban area. A unit of required investment is large compared with increase of demand.
(b) Investment cost of facilities	Track, electrification facilities, signalling, telecommunications, station facilities, equipment of depot/workshop: These do not require so large investment cost compared with the above and do not different in urban areas from in other areas.
(c) Investment cost of rolling stock	Rolling stock: This requires investment cost corresponding increasing demand step by step.
(d) Operation expenses	Expenses for management, operation, maintenance, etc.

Remarks: Interest of borrowing for investment and depreciation are examined together with investment cost.

In order to secure funds for urban transport, which has problems of profitability, subsidies and compensation (if necessary) from the government and value capture should be executed. Resources and flow of funds for railway / mass rapid transit system improvement/operation are shown in Table 1.7.2.

Table 1.7.2 Resources and Flow of Funds for Railway/MRT System Improvement and Operation

Benefit		Beneficiary →	Financial Source →	Type of Funds
Direct Benefit	Transport	Passenger/Commuter	Fare	Fare
			Reserve Fund System	Fare
		Employer	Special Payment	Compensation
Indirect Benefit (Public Welfare)	Promotion of Socio-economic Activity	People	General Tax Earmarked Tax	Subsidy/Grant-in-aid
	Environment-friendly and Others			
	Easement of Congestion of Other Lines			Compensation (For Fare Ceiling)
	Easement of Congestion of Road	Car Users	Earmarked Tax Funds for Road Construction	
Indirect Benefit (Development)	Development Gain	Developer	Burden-sharing by Developer	Value Capture
		Railway/MRT Enterprise as Developer	Internalization of Development Gain	
		Owner of Real Estate	Real Estate Tax Earmarked Tax Additional Collection of General Tax	Subsidy as Value Capture through Tax
			Special Imposition	Value Capture
(Loss)		(Passenger of Other Unrelated Lines of the Railway/MRT Enterprise)	Internal Assist within the Railway/MRT Enterprise	Raised Fare

1.7.3 Subsidies, Grants-in-aid and Compensation

Around the world various subsidies, grants-in-aid and compensation are introduced to enterprises of railways / mass rapid transit systems for urban transport as financial resources for both investment costs and operation expenses.

Subsidies and grants-in-aid are carried out to solve the problems of the unprofitability of railways / mass rapid transit systems for urban transport which require huge construction cost especially for land and structures in urban areas, because railways/MRT support their activities and are an indispensable part of the infrastructures of large-scale cities.

Subsidies are also carried out to hold down fare levels politically for people and enterprises in large-scale city areas so that they can use transport means easily.

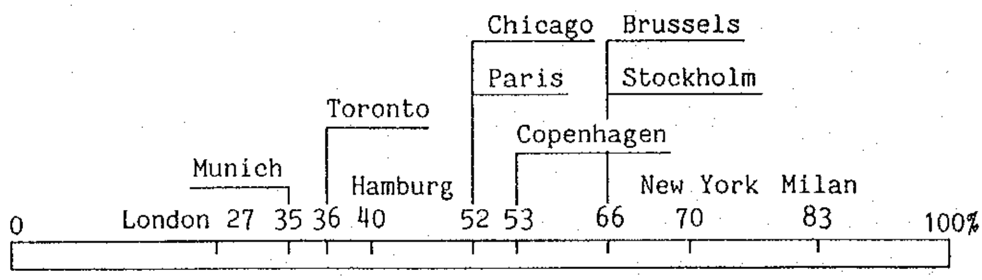
In case a system of compensation is established, in principle subsidies for operation expenses are not recommendable because they continue forever, they make transport enterprises lose their desire for rationalization, and in most cases, urban transport with reasonable fares can be profitable because of sufficient demand if appropriate assistance for investment costs, which are just too large, has been carried out.

Resources for subsidies are mainly general tax. In Germany, a mineral oil tax (earmarked tax) is also allocated, the purpose of which is to reinforce railways / mass rapid transit systems, ease traffic congestion and air pollution in large scale cities. In the USA, in addition to general funds, various types of earmarked taxes and an additional collection of general taxes are executed at the Federal, State and City levels, respectively. In Japan, in some cities such as Sapporo, Kita Kyushu, Fukuoka and Sendai, a certain portion of specified local taxes and an additional collection of taxes are used for subways or a monorail. In Japan, funds for road construction are allocated for infrastructures for monorails and new transport systems located above streets by regarding them as a part of the street.

In France, as resources for compensation of discounted fares (for commuting), a "Payment of Transport" system has been executed. Enterprises in the related areas should pay a prescribed rate (0.5% ~ 2.4%) corresponding to salary.

As for subsidies which are a means of value capture, they are described in section "1.7.4 Value Capture".

Some examples of subsidies, grants-in-aid and compensation for railways / mass rapid transit systems in various countries are shown in Table 1.7.3. Examples of share of total subsidies for both investment costs and operation expenses (excluding depreciation and reserve funds for renewal) for expenditure on subways around the world are shown in Fig. 1.7.1.



Note: Total expenditure consists of operational expenditure (excluding depreciation and reserve fund for renewal) and capital expenditure.

Fig. 1.7.1 International Comparison of Share of Subsidy in Total Expenditure for Subways

1.7.4 Value Capture

"Value Capture" is a system to take in a portion of gains obtained by development. The development gains are a large part of the benefits created by a railway / mass rapid transit system project. However, because of its difficulty as a method, value capture has not been carried out sufficiently. Therefore, if it can be realized, it can promote railway / mass rapid transit system projects.

That is to say, the argument for value capture is

- to correct inequalities in burden sharing among beneficiaries,

- to solve the problem of a shortage of funds for establishment of an urban public transport system whose level is realized to be lower than the level required as a necessary socio-economic infrastructure.

In many countries, much effort to realize "Value Capture" has been made, efforts to systematize and to quantify the gains have been carried out, and in some countries, a system

Table 1.7.3 Examples of Subsidy System for Railway/Mass Rapid Transit System

Country	Enterprise	Subsidy System	Resource of Funds
Japan	Subway	Subsidy for construction 70% (In 10-years installment) (Except portion equivalent to capital)	Government 35% Local government 35% General funds
		Capital 20%	Local government General funds
	New town railway	Subsidy for construction 36% (In 6-years installment)	Government 18% Local government 18% General funds
	Private railway in large city areas	Interest subsidy of a portion exceeding 5%	Government 1/2 Local government 1/2 General funds
	Monorail and new transport system	Burden regarding as a part of street (Infrastructure construction only: Actually approx. 57% of all)	Government 52.5% Local government 47.5% Funds for road (Earmarked taxes)
France	RATP (Parisian Transport Autonomous Administration SNCF (National Railway)	Subsidy for construction 80%	Government 40% Local government 40% General funds
		Compensation for hold-down of fare (* 32%) Compensation for discounted fare for commuting (* 20%) * Proportion to total revenues (1989)	Government 70% Local government 30% Enterprises in the related area "Payment of Transport" corresponding salary payed by the enterprises (0.5% - 2.4%)
Germany	Municipal enterprise (U-Bahn) DB (National Railway/S-Bahn)	Subsidy for construction ** 60% + x ** 75% Primary East Germany	Federal government * 60% U-Bahn: State/City 40% (Negotiation) S-Bahn: State/DB 40% (Negotiation) Federal government: Mineral oil tax State/city: General funds
		Compensation for hold-down of fare	U-Bahn: Federal government: General tax S-Bahn: State General tax
USA	MTA (Metropolitan Transport Authority - New York) Others	Subsidies for investment Subsidies for operation	Federal government, State government, other Local government General funds (mainly) Earmark taxes
		Remarks: - "Urban Mass Transit Act of 1964" has introduced the subsidy by the Federal government - "Federal-Aid Highway Act of 1973" allowed to allocate "the Highway Trust Fund" to Urban mass transit. - "Intermodal Surface Transportation Efficiency Act of 1991" expanded above.	

has been actually introduced. To realize value capture, is also an important matter for execution of the projects of this Study.

Beneficiaries of development are classified into the following two groups.

- Land and real estate developers
- Land and real estate owners

The former are easily made to share the burden, because their causal relation to the railway/mass transit system project is clear and they are just managing funds. Therefore, in many countries by various methods value capture from developers has been executed.

The latter are not easily made to share the burden, because their numbers are so much greater and their situations are more varied. They can not easily be specified and in most cases, they only own land and real estate and do not possess and manage cash unless they sell their land and real estate.

Measures of value capture are classified as follows.

- Subsidies allocated out of general taxes related to land and real estate such as real estate tax, city planning tax, residentce tax, enterprise tax, which increase in price or volume with the execution of the development
- Subsidies allocated out of earmarked taxes or additional collection of general taxes
- Development charges, provision of developed land instead of charges, provision of land for the right-of-way
- Internalization of windfall benefits, by transport system enterprises
- Special imposition on the beneficiaries, such as related owners of land and real estate

An example of value capture actually executed is that of the subway project in Los Angeles, California in the USA. The first stage of the project is a 7 km line. The subsidies for investment are as follows and the shortage amounting to 11% is expected to be borne as value capture because the real estate owners around stations do not pay justly for the increase of property value and profitability.

Subsidies	89%	
Federal government	56%	
State	18%	
County	13%	(Additional collection of sales tax 0.005% - Also a type of value capture)
City	2%	
Value capture	11%	(Special assessment district)

The system executed is to settle the "Benefit Assessment Districts" as follows:

Area:	Commercial/business district	1/2 mile (805 m) walking distance from the center of the station
	Suburbs	1/3 mile (536 m) walking distance from the center of the station

Rate: US$ 0.3 per sq. foot (US$ 3.2 per m^2) of properties

Collection is postponed until commencement of operation.

In Japan, in the case of the New Joban Line now being planned, the amount of the benefit of development is estimated to be three or four times the construction cost. However, it is difficult to obtain a sufficient solution for establishing a system of recycling the benefit (value capture). If this project is implemented successfully, it will be a good example of a comprehensive project that can satisfy demand for a favorable housing environment as well as the requirement of alleviating the extremely heavy congestion of the existing railway.

Internalization of windfall benefits can be realized in the case that a transport enterprise executes the development project by itself, because the burden-sharing is easily designed or the unprofitability of the transport project can be cancelled by the profit of the development. Examples in Japan are described in "1.7.8".

1.7.5 Reserve Fund System

The reserve fund system in Japan was established in 1986 for railway reinforcement such as track quadrupling of the existing lines of private companies in specified large cities.

This system allows them to charge additional fare in advance of the completion of the reinforcement project as the funds for the investment.

With this system interest within the investment cost is reduced. Therefore, fares after completion of the project can be made lower. This system is suitable for easing congestion on the existing lines.

1.7.6 Public Service Obligation (PSO)

The SRT Master Development Plan Study, issued in May, 1993, proposes a system of "Public Service Obligation (PSO)". "Governments have social responsibilities, railways do not. Not recognizing this simple truth has paralyzed many of the world's railways in the past. There the public good requires railways to offer services at less than cost, it should clearly be the responsibility of the government to shoulder these losses." says the study report.

This system is designed to resolve the above problem. This demands that each service should be considered on its own, which respectively requires that each services cost accounting should be fully executed so that its individual loss can be known. It makes the SRT's responsibilities clear and gives the SRT incentives to make innovations and raise efficiency.

To execute various measures such as maintaining a low fare level, operating a light-traffic line, constructing a new line (which requires a huge investment compared with the available fares) by borrowing many tempt both the Government and the enterprise to easy expenses and investment which leave the enterprise in danger of ruin. It is especially undesirable to get into debt for expenses.

On the other hand, to make up annual losses by general subsidies leads the enterprise to irresponsible management causing an increase of subsidies.

PSO is thus a suitable system for such a public enterprise as the SRT. The Government, through a cabinet resolution, has already decided to implement it but it has not been actually executed yet.

In order to prevent the accumulation of debt and activate the SRT, it would be desirable to start a PSO system as soon as possible.

In Europe and America, PSO systems have already been carried out. Subsidies, grants-in-aid and compensation mentioned in "1.7.3" based on PSO are clearly provided.

1.7.7 BOT System

In recent years, a strong movement has been in progress in Thailand and other countries to implement a new policy concerning the construction of infrastructures for their countries. This policy aims to entrust the construction and operation of the facilities to enterprises in developed countries, so as to utilize the output for elevation of the economic level of the developing countries concerned. That is so say, the above enterprises "Build and Operate" the facilities and, after a specific period (for example, 30 years), "Transfer" them to the country concerned. This is the BOT system that has been attracting public attention recently. The purpose of the BOT system is to make a developed country supplement the shortage of funds in a developing country, and the improvement of management efficiency through private operation is also expected. Thus it can be said that the BOT system is a kind of international method that utilizes private funds.

Since the BOT system has quick effects on urban development in developing countries, it is considered most important to give the urban transport systems the independence in deciding policies of operation including fares that constitutes the revenue source of these transport systems. This is a precondition for realizing the projects by introduction of the BOT system.

However, the BOT system can solve only the problem of funds and management. It can not solve the important problem of the unprofitability of railway / mass rapid transit projects in large cities because of the very high investment cost and the requirment of a low fare level . A railway / mass rapid transit system needs the participation of the government and recognition as a necessary part of the infrastructure of the urban area. Therefore, it is essential to clarify the privileges of the urban transport systems concerning the development of the regions along the routes and also clarify the matters to be guaranteed by the national government, such as investment and assistance from the government.

The big problem with BOT system is that it is difficult to be controled by the government, especially on schedule as an important project, because it is carried out from a business view point. The system is not suitable for vital national projects requiring government leadership and having a large influence on the life of the people.

It is preferable for realizing railways / mass rapid transit systems in the Bangkok Metropolis that the government determines to execute the system on its own responsibility. If the BOT system is adopted, it is essential to set forth a certain burden-sharing and reserve the leadership supported by it of the government.

1.7.8 Some Examples in Japan

(1) An outline of public subsidy systems for urban railway development

An outline of public subsidy systems in Japan are shown in Table 1.7.4.

The "Subway System" and "New Town System" are the systems which supplement construction costs of subways and new town railways by subsidies from the government and the local government. The Japan Railway Construction Public Corporation's "P line" and "CD line" systems are systems which supplement a portion of interest exceeding 5 percent on the loans for construction costs through the corporation while the amount of such a grant-in-aid naturally increases or decreases subject to market interest trends.

The "Railway Development Fund System" is a system which assists, by an interest-free loan covering 80 percent of construction costs, while the principal is unredeemable for five years and repayable in 15 years.

The "Reserve Fund System" is a kind of railway development system shared by users. A part of the construction costs (not more than 25 percent) is collected in advance from the users to be held in reserve. (Refer to 1.7.5.)

(2) Cases of recent new lines

Cases of newly opened subway lines are shown in Table 1.7.5. Each of them is in operation over a limited section and construction of an extended section is still in progress.

Cases of construction of urban railway projects either under planning or in progress are shown in Table 1.7.6. In the cases of the Joban new Line and the No. 7 line of the Teito Rapid Transit Authority, plans are being made on the basis of interest free loan systems from the central government (Railway Development Fund established in recent years) and by local governments; long-term forecasts of the revenue and expenditure of the projects are also given in the Table.

(3) Burden-sharing by developers along the railway line

1) System of burdens on new town developers

As for the construction cost of a railway line located inside a large-scale new town which is connected with the center of the city through this railway line, a system to make the relevant new town developer bear a part of the construction cost is established. The contents of the burdens on the developer are as follows.

- Land:

  The developer should provide land at the original land price (i.e. excluding the costs for new town development).

- Construction Costs:

  The developer should bear 50% of the construction costs below the formation level of the railway.

Together with the burden mentioned above borne by the new town developer, the railway company can be given a new town railway subsidy from the central and local governments for the construction cost which the company bears, including the cost of the relevant new line up to the nearest existing station.

In principle, both the systems above are applied to a local government or third sector railway.

2) Example of internalization of the profit by the railway company

Tokyu Den'entoshi Line (Den'entoshi means rural city.) is a railway line which connects the project site (Den'entoshi) with the center of Tokyo through urban areas. In this project, Tokyu Corporation, which was its relevant developer and railway line company, conducted land readjustment work by itself, and smoothly bore the costs for providing the railway line with reserved land equivalent to the burdens the developer should bear. (Refer to 1.4.2 (6))

- Development area:
  3,200ha, 18km to 36km away from the center of Tokyo

- Length of the newly-extended section:
  20.1km (19.3km inside the new town) electrified double-track line

(4) Subsidies in of regard to street construction projects

Monorails and new transport systems are considered to indirectly play a role in coping with a part of road traffic as auxiliary systems to road transport. When they are constructed above roads, subsidies for columns, girders and other items regarded as infrastructure are given to the relevant projects. The ratio of subsidies given by the central government and the relevant local governments is 52.5% and 47.5%.

(Reference materials for 1.7.1 - 1.7.5, 1.7.8: Reports of the Railway Development Fund, March, 1992, and Seminar on Urban Transport in Thailand, Feb., 1992, JARTS)

Table 1.7.4 Outline of Subsidy System for Urban Railway/Mass Rapid Transit System

System / Item	Subway System	New Town System	Japan Railway Construction Public Corporation P Line System
Financial assistance system	Subsidies for construction costs of underground mass rapid transit systems	Subsidies for construction costs of new town railways	Grant-in-aid for interest on construction costs of loaned lines and transferred lines
Type of project	Construction of subways by Teito Rapid Transit Authority and local governments (Public management)	Construction of railway linking a new town and the nearest railway station in accordance with a new residential area development project or a re-zoning project, of three large city areas	Construction of private railways by Japan Railway Construction Public Corporation in three large city areas as listed below: - Subway and through-operation lines into subway, and - Construction of a new line for a new town
Subjected railway undertaking body	Public managements: Sapporo, Sendai, Tokyo, Yokohama, Nagoya, Kyoto, Osaka, Kobe and Fukuoka Teito Rapid Transit Authority	Local governments and third sectors operating new town railway business	Private railway companies in three large city areas
Amount of subsidies	Subsidizing 70 percent of construction costs [Central government 1/2, Local government 1/2]	Subsidizing 36 percent of construction costs [Central government 1/2, Local government 1/2]	Grant-in-aid for interest for a portion exceeding 5 percent of interest [Central government 1/2 Local government 1/2]

System / Item	Japan Railway Construction Public Corporation C, D Line system	Railway Development Fund	Reserve Fund System
Financial assistance system	Grant-in-aid for interest on construction costs of loaned lines and transferred lines	Interest-free loan system for large urban railways	Reserves for railway development in specified cities
Type of project	Construction of JR lines in large cities by Japan Railway Construction Public Corporation	Construction of new lines and double tracking by the Japan Railway Construction Public Corporation in accordance with the Integration Law Construction of new lines of Teito Rapid Transit Authority	Work related to integrated and large scale construction or improvement of facilities of urban railways in large city areas Quadruple tracking, Transport capacity reinforcement work (e.g. increasing train length), Double tracking work
Subjected railway undertaking body	Japan Railway Companies	Third sector Teito Rapid Transit Authority (construction of new lines)	Private railway companies in three large city areas
Amount of subsidies	Grant-in-aid for interest for a portion exceeding 5 percent [Central government 1/1]	Interest-free loan for 80 percent of construction costs [Central government's Railway Development Fund 1/2 Local government 1/2]	Advance levies borne by users and resultant reserves to cover up to 1/4 of construction costs

Table 1.7.5 Cases of Recently Opened Subway Lines

Item \ Name of Line	No. 7 Line of Teito Rapid Transit Authority (Nanboku Line)	No. 12 Metropolitan Line (Radial Section)
	Komagome - Akabane-Iwabuchi	Nerima - Hikarigaoka
Name of undertaking body	Teito Rapid Transit Authority (Special Corporation)	Bureau of Transportation of Tokyo Metropolitan Government
Particulars of undertaking body		
Capital stock	¥58.1 billion (13.5) *	--
Investor	[Central government ¥31.0 billion (7.2) Tokyo Metropolitan Government ¥27.1 billion (6.3)]	
Particulars of undertaking		
Total length of line (section)	6.8 km (Komagome - Akabane-Iwabuchi)	4.8 km (Nerima - Hikarigaoka)
Number of stations	6 stations	4 stations
Year of commencement of operation	November 1991	December 1991
Construction period	1986 - 1991	1985 - 1991
Construction costs	Approx. ¥130 billion (30.2)	Approx. ¥113 billion (26.3)
Kind of structure	Underground	Underground
Transport density	At completion of entire line 21.4 km: 134,000 passengers/km day	At commencement of operation of radial section's entire line 13.9 km: 122,000 passengers/km day
Raising of construction funds	Subway construction subsidy system Subsidies Central government 35% Local government 35% Loans 30% Government investment and loan program, credit, etc.	Subway construction subsidy system Subsidies Central government 35% Local government 35% Loans 30% Government investment and loan program, credit, etc.

* in brackets: billion baht (1 baht: 4.3 yen)

Table 1.7.6 Cases of Urban Railway Projects under Planning or Construction

Name of line	Joban New Line (Construction of a new line)	No. 7 Line of Teito Rapid Transit Authority (Komagome - Meguro) (Construction of a new subway line)
Name of undertaking body	Capital Region New Urban Railway Co., Ltd. (Third sector)	Teito Rapid Transit Authority (Special corporation)
Particulars of undertaking body		
Capital stock	¥5.6 billion (1.3)	¥58.1 billion (13.5)
Investor	Tokyo Metropolis, Ibaraki, Chiba, Saitama Prefecture and 12 other local governments	Central government and Tokyo Metropolis
Particulars of undertaking		
Total length of line (section)	58.3 km (Akihabara - Tsukuba)	14.6 km (Meguro - Komagome)
Number of stations	19 stations	13 stations
Estimated year of commencement of operation	2000 (1992 - 2000)	1995
Construction period	1992 - 2000	1989 - 1995
Construction costs	Approx. ¥800 billion (190.0)	Approx. ¥350 billion (80.0)
Kind of structure	Underground 27% Elevated 73% Ground level	Underground
Transport density	At commencement of operation 134, 000 passengers/km day	At commencement of operation 134,000 passengers/km day
Raising of construction funds	Railway Development Fund's interest-free loan system Interest-free loans Central government 40% Local government 40% Loans etc. 20%	Railway Development Fund's interest-free loan system Interest-free loans Central government 40% Local government 40% Loans, government investment and loan program, credit, etc. 20%
Revenue and expenditure forecast		
Balance turning to surplus in a single year	19th year	12th year
Accumulated loss turning to surplus	30th year	23rd year
Funds turning to surplus in a single year	16th year	26th year
Accumulated funds turning to surplus	28th year	28th year

* In brackets: billion baht (1 baht: 4.3 yen)

1.8 Cost/Expense Estimation and Implementation Period

Based on the estimated demand and integrated with the urban development plan, railway improvement plan is formed.

A project list including estimated investment costs in the basic case and implementation period is shown in Table 1.8.1. The project period is 15 years from 1996 to 2010. The year of 2010 is the target year of this project and the project life is 30 years until 2015. The project period is phased into the following three phases, because a construction term of five years for a big project such as railway improvement is thought to be adequate and about ten years divided into two terms is thought to be adequate for a large-scale urban development.

- Project period 1996 - 2010 (15 years)
  - Step I 1996 - 2000
  - Step II 2001 - 2005
  - Step III 2006 - 2010
- Target year 2010
- Project life 1996 - 2025 (30 years)

Estimated annual costs, expenses and revenue in the basic case are shown in Table 1.8.2.

Table 1.8.1 List of Railway Improvement Project

Project	Schedule (I: 96–2000, II: 01–05, III: 06–10)	Item	Costs Million Baht Total	FC	LC
1. COMMUTER SERVICE					
(1) Eastern Line					
Yommarat - Hua Mak * 14.0km	Electrification	Station/Structure/Track	750	360	390
Hua Mak - Hua Takhe 15.5km		Electric Facilities	1600	1420	180
		Depot/Workshop	710	370	340
* : Electrification Only		Electric Railcar	2070	2070	
			5130	4220	910
Hua Takhe - Chachoengsao 29.1km	Electrification	Station/Structure/Track	930	290	640
		Electric Facilities	1100	970	130
		Depot/Workshop	650	350	300
		Electric Railcar	1710	1710	
			4390	3320	1070
Urgent/Provisional Measures		At-grade Crossing Improvement			
		Diesel Railcar	440	440	
Subtotal (Eastern Line except SBIA N.L.)			9960	7980	1880
SBIA New Line Lat Krabang - SBIA 7.0km		Station/Structure/Track	2110	610	1500
		Electric Facilities	320	290	30
		Depot/Workshop	190	110	80
		Electric Railcar	450	450	
			3070	1460	1610
Total Eastern Line (Including SBIA N.L.)			13030	9440	3590

No.2

Project	Schedule (I: 96–2000, II: 01–05, III: 06–10)	Item	Cost Million Baht Total	FC	LC
(2). Northern Line					
Hua Lamphong	Electrification	Station/Structure/Track	420	130	290
- Khlong Rangsit * 28.5km		Electric Facilities	2060	1750	310
Khlong Ragsit - Chiang Rak		Depot/Workshop	1110	530	580
9.0km		Electric Railcar	4280	4280	
* : Electrification Only					
			7870	6680	1190
	Electrification				
Chiang Rak - Ayutthaya 33.6km		Station/Structure/Track	1640	510	1130
		Electric Facilities	1830	1550	280
		Depot/Workshop	700	460	240
		Electric Car	2300	2300	
			6470	4820	1650
Urget/Provisional Measures		At-grade Crossing Improvement			
Total Northern Line			14340	11500	2840
(3) Southern Line					
Yommarat - Taling Chan					
* 10.0km	Electrification	Station/Structure/Track	620	220	400
Taling Chan		Electric Facilities	1030	900	130
- Sala Ya 13.0km		Depot/Workshop	720	390	330
* : Electrification Only		Electric Railcar	1450	1450	
			3820	2960	860
Sala Ya - Nakhon Pathom	Electrification				
39.0km		Station/Structure/Track	980	240	740
		Electric Facilities	1610	1410	200
		Depot/Workshop	190	110	80
		Electric Railcar	1720	1720	
			4500	3480	1020
Urgent/Provisional Measures		At-grade Crossing Improvement	850	850	
		Diesel Railcar			
Total Southern Line			9170	7290	1880

No.3

Project	Schedule I (96–2000)	Schedule II (01–05)	Schedule III (06–10)	Item	Cost Million Baht Total	FC	LC
(4) Maeklong Line							
Hua Lamphong - Pho Nimit * 5.0km		Electrification		Station/Structure/Track	2680	680	2000
Pho Nimit - Maha Chai 30.0km				Electric Facilities	1630	1430	200
				Depot/Workshop	680	340	340
* : Electrification Only				Electric Railcar	2140	2140	
				(Including Double-tracking)	7120	4590	2530
Rehabilitation				Rehabilitation	100	60	40
Total Maeklong Line					7220	4590	2630
Total Commuter Service					43760	32820	10940

No.4

Project	Schedule			Item	Cost Million Baht		
	I 96 2000	II 01 05	III 06 10		Total	FC	LC
2. INTERCITY EXPRESS							
(1) 1st Stage				At-grade Crossing Impr.			
				Diesel Railcar			
				Eastern Line	570	570	
				Northern/Northeastern Line	1150	1150	
				Southern Line	990	990	
					2710	2710	
(2) 2nd Stage				Diesel Railcar			
				Eastern Line	1120	1120	
				Northern/Northeastern Line	1710	1710	
				Southern Line	1450	1450	
					4280	4280	
				Crossing/Refuge Loop			
				Eastern Line	210	140	70
				Northern/Northeastern Line	420	280	140
				Southern Line	300	200	100
					930	620	310
(3) Total				Total			
				Eastern Line	1900	1830	70
				Northern/Northeastern Line	3280	3140	140
				Southern Line	2740	2640	100
Total Ic. Express					7920	7610	310

No.5

Project	Schedule I (96–2000)	Schedule II (01–05)	Schedule III (06–10)	Item	Cost Million Baht Total	FC	LC
Ongoing Projects Out of THIS STUDY							
(1) Hopewell Project							
Yommarat - Hua Mak				(Delayed 2 Years)			
Yommarat - Dong Muang				(Delayed 2 Years)			
Hua Lamphong - Yommarat				(Delayed 2 Years)			
Dong Muang - Khlong Rangsit				(Delayed 2 Years)			
Yommarat - Thon Buri							
Thon Buri - Taling Chan							
HuaLamphong - Won Wien Yai							
Wong Wien Yai - Pho Nimit							
(2) SRT Track Adding Project							
Eastern Line							
Hua Mak - Chachoengsao				Double Tracking			
Northern Line							
Khlong Ransit - Bang Phachi J.				Triple Tracking			
Ban Phachi J. - Lop Buri				Double Tracking			
Northeastern Line				Double Tracking			
Ban Phachi J. - Map Kabao							
Southern Line				Double Tracking			
Bang Sue J. - Nakhon Pathom							

Table 1.8.2 (1) Estimated Annual Costs, Expenses and Revenue of Railway Improvement Project

(Commuter Service)

Unit : Million Baht

Item / Year & Phase	Cost & Expenses					Revenue	Profit	NPV		
	Investment Cost			Expenses	Total (A)	(B)	(B)-(A)	Discounted by		
	Facilities	Rolling Stock	Total					7%	9%	11%
1996	1,140	0	1,140	0	1,140	0	-1,140	-1,140.0	-1,140.0	-1,140.0
1997	930	60	990	140	1,130	90	-1,040	-972.0	-954.1	-936.9
I 1998	1,220	80	1,300	180	1,480	100	-1,380	-1,205.3	-1,161.5	-1,120.0
1999	2,770	100	2,870	230	3,100	130	-2,970	-2,424.4	-2,293.4	-2,171.6
2000	3,050	4,740	7,790	270	8,060	160	-7,900	-6,026.9	-5,596.6	-5,204.0
2001	710	110	820	750	1,570	860	-710	-506.2	-461.5	-421.4
2002	1,410	120	1,530	770	2,300	930	-1,370	-912.9	-816.9	-732.5
II 2003	1,820	120	1,940	770	2,710	970	-1,740	-1,083.6	-951.8	-838.1
2004	4,410	130	4,540	790	5,330	1,010	-4,320	-2,514.3	-2,168.1	-1,874.6
2005	5,060	6,470	11,530	790	12,320	1,070	-11,250	-6,119.3	-5,179.8	-4,397.9
2006	70	60	130	1,250	1,380	1,890	510	259.3	215.4	179.6
2007	210	60	270	1,250	1,520	2,050	530	251.8	205.4	168.2
III 2008	320	60	380	1,250	1,630	2,220	590	262.0	209.8	168.6
2009	1,350	70	1,420	1,270	2,690	2,400	-290	-120.3	-94.6	-74.7
2010	1,880	5,230	7,110	1,270	8,380	2,540	-5,840	-2,264.9	-1,747.6	-1,354.8
2011			0	1,450	1,450	2,830	1,380	500.2	378.9	288.4
2012			0	1,450	1,450	2,830	1,380	467.5	347.6	259.8
2013			0	1,450	1,450	2,830	1,380	436.9	318.9	234.1
2014			0	1,450	1,450	2,830	1,380	408.3	292.6	210.9
2015			0	1,450	1,450	2,830	1,380	381.6	268.4	190.0
2016			0	1,450	1,450	2,830	1,380	356.6	246.2	171.2
2017			0	1,450	1,450	2,830	1,380	333.3	225.9	154.2
2018			0	1,450	1,450	2,830	1,380	311.5	207.3	138.9
2019			0	1,450	1,450	2,830	1,380	291.1	190.1	125.2
2020			0	1,450	1,450	2,830	1,380	272.1	174.4	112.8
2021			0	1,450	1,450	2,830	1,380	254.3	160.0	101.6
2022			0	1,450	1,450	2,830	1,380	237.6	146.8	91.5
2023			0	1,450	1,450	2,830	1,380	222.1	134.7	82.4
2024			0	1,450	1,450	2,830	1,380	207.6	123.6	74.3
2025			0	1,450	1,450	2,830	1,380	194.0	113.4	66.9
Total	26,350	17,410	43,760	32,730	76,490	58,870	-17,620	-19,642.5	-18,606.5	-17,447.9
FIRR							-0.0403			
NPV (mmBts)								-19,642.5	-18,606.5	-17,447.9

Table 1.8.2 (2) Estimated Annual Costs, Expenses and Revenue of Railway Improvement Project

(Intercity Express Service)

Unit : Million Baht

Item / Year & Phase	Cost & Expenses					Revenue	Profit	NPV		
	Investment Cost			Expenses	Total (A)	(B)	(B)-(A)	Discounted by		
	Facilities	Rolling Stock	Total					7%	9%	11%
1996	0	2,710	2,710	0	2,710	0	-2,710	-2,710.0	-2,710.0	-2,710.0
1997	0	0	0	160	160	540	380	355.1	348.6	342.3
I 1998	300	0	300	160	460	570	110	96.1	92.6	89.3
1999	300	0	300	160	160	610	150	122.4	115.5	109.7
2000	330	2,010	2,340	160	2,500	640	-1,860	-1,419.0	-1,317.7	-1,225.2
2001			0	270	270	680	410	292.3	266.5	243.3
2002			0	270	270	740	470	313.2	280.2	251.3
II 2003			0	270	270	780	510	317.6	279.0	245.6
2004			0	270	270	850	580	337.6	291.1	251.7
2005	0	1,470	1,470	270	1,740	900	-840	-456.9	-386.8	-328.4
2006			0	360	360	950	590	299.9	249.2	207.8
2007			0	360	360	1,030	670	318.3	259.6	212.6
III 2008			0	360	360	1,100	740	328.6	263.1	211.5
2009			0	360	360	1,180	820	340.3	267.5	211.2
2010	0	800	800	360	1,160	1,250	90	34.9	26.9	20.9
2011			0	410	410	1,320	910	329.8	249.8	190.2
2012			0	410	410	1,320	910	308.2	229.2	171.3
2013			0	410	410	1,320	910	288.1	210.3	154.4
2014			0	410	410	1,320	910	269.2	192.9	139.1
2015			0	410	410	1,320	910	251.6	177.0	125.3
2016			0	410	410	1,320	910	235.2	162.4	112.9
2017			0	410	410	1,320	910	219.8	149.0	101.7
2018			0	410	410	1,320	910	205.4	136.7	91.6
2019			0	410	410	1,320	910	192.0	125.4	82.5
2020			0	410	410	1,320	910	179.4	115.0	74.4
2021			0	410	410	1,320	910	167.7	105.5	67.0
2022			0	410	410	1,320	910	156.7	96.8	60.3
2023			0	410	410	1,320	910	146.4	88.8	54.4
2024			0	410	410	1,320	910	136.9	81.5	49.0
2025			0	410	410	1,320	910	127.9	74.8	44.1
Total	930	6,990	7,920	9,940	17,860	31,620	13,760	1,784.7	520.8	-348.4
FIRR							0.1011			
NPV (mmBts)								1,784.7	520.8	-348.4

Table 1.8.2 (3) Estimated Annual Costs, Expenses and Revenue of Railway Improvement Project

(Adding up Both the Services)

Unit : Million Baht

Phase	Item / Year	Cost & Expenses: Investment Cost: Facilities	Rolling Stock	Total	Expenses	Total (A)	Revenue (B)	Profit (B)-(A)	NPV Discounted by 7%	9%	11%
I	1996	1,140	2,710	3,850	0	3,850	0	-3,850	-3,850.0	-3,850.0	-3,850.0
	1997	930	60	990	300	1,290	630	-660	-616.8	-605.5	-594.6
	1998	1,520	80	1,600	340	1,940	670	-1,270	-1,109.3	-1,068.9	-1,030.8
	1999	3,070	100	3,170	390	3,560	740	-2,820	-2,302.0	-2,177.6	-2,062.0
	2000	3,380	6,750	10,130	430	10,560	800	-9,760	-7,445.9	-6,914.2	-6,429.2
II	2001	710	110	820	1,020	1,840	1,540	-300	-213.9	-195.0	-178.0
	2002	1,410	120	1,530	1,040	2,570	1,670	-900	-599.7	-536.6	-481.2
	2003	1,820	120	1,940	1,040	2,980	1,750	-1,230	-766.0	-672.9	-592.4
	2004	4,410	130	4,540	1,060	5,600	1,860	-3,740	-2,176.7	-1,877.0	-1,622.9
	2005	5,060	7,940	13,000	1,060	14,060	1,970	-12,090	-6,576.2	-5,566.6	-4,726.3
III	2006	70	60	130	1,610	1,740	2,840	1,100	559.2	464.7	387.4
	2007	210	60	270	1,610	1,880	3,080	1,200	570.1	465.0	380.7
	2008	320	60	380	1,610	1,990	3,320	1,330	590.5	472.9	380.2
	2009	1,350	70	1,420	1,630	3,050	3,580	530	219.9	172.9	136.5
	2010	1,880	6,030	7,910	1,630	9,540	3,790	-5,750	-2,229.9	-1,720.7	-1,334.0
	2011			0	1,860	1,860	4,150	2,290	830.0	628.7	478.6
	2012			0	1,860	1,860	4,150	2,290	775.7	576.8	431.2
	2013			0	1,860	1,860	4,150	2,290	725.0	529.2	388.5
	2014			0	1,860	1,860	4,150	2,290	677.5	485.5	350.0
	2015			0	1,860	1,860	4,150	2,290	633.2	445.4	315.3
	2016			0	1,860	1,860	4,150	2,290	591.8	408.6	284.0
	2017			0	1,860	1,860	4,150	2,290	553.1	374.9	255.9
	2018			0	1,860	1,860	4,150	2,290	516.9	343.9	230.5
	2019			0	1,860	1,860	4,150	2,290	483.1	315.5	207.7
	2020			0	1,860	1,860	4,150	2,290	451.5	289.5	187.1
	2021			0	1,860	1,860	4,150	2,290	421.9	265.6	168.6
	2022			0	1,860	1,860	4,150	2,290	394.3	243.6	151.9
	2023			0	1,860	1,860	4,150	2,290	368.5	223.5	136.8
	2024			0	1,860	1,860	4,150	2,290	344.4	205.1	123.3
	2025			0	1,860	1,860	4,150	2,290	321.9	188.1	111.0
Total		27,280	24,400	51,680	42,670	94,350	90,490	-3,860	-17,857.8	-18,085.7	-17,796.2
FIRR								-0.0067			
NPV (mmBts)									-17,857.8	-18,085.7	-17,796.2

1.9 Economic Evaluation

The economic evaluation plays an important role for planners and policy makers in making a decision to implement a project. A project which could bring a reasonable benefit to a country is usually recommneded to be implemented. In other words, it is considered as a desirable project, taking into account both benefit and cost. The major objectives for economic evaluation of this study are to:

- assess the project viability;
- find the most appropriate alternative for railway improvement plans; and
- establish the most economical investment timing.

1.9.1 Classification of Benefit

(1) Time saving benefit

As a result of railway improvement, travel time by train will reduce. Recently, income of people in the study area especially in Bangkok Metropolitan Region (BMR) has increased considerably due to a rapid economic growth, this leads to the larger time savings, which is a major portion of total benefit.

Passengers who can save time are classified into two groups

1) Railway Users

This group of passengers consists of existing and new railway users. Existing railway users could save travel time due to the improvements of railway and feeder transport to / from railway station. New passengers are those who previously used other modes of transport, such as passenger cars, city buses, tuk-tuk, or taxis. These new passengers could be attracted to train if travel time by train is shorter.

2) Non-Railway Users

Those who use other transport modes could also save travel time if a part of them transfer to train resulting in a lower degree of traffic congestion on roads.

(2) Vehicle operating cost saving

Vehicle Operating Cost (VOC) consists of the following cost components

- fuel and oil;
- maintenance;
- wage (for commercial vehicles only);
- depreciation and interest costs; and
- tire wear

(3) Other benefit

As a result of integrated railway and urban development, other benefits, apart from those aforementioned, could be obtained. However, this type of benefit is quite difficult to be estimated in monetary terms. These benefits include:

- tourism development;
- industrial development;
- reduction in accident, and
- higher living standard.

1.9.2 Estimation of Benefit

In order to estimate various types of benefit, the following variables are needed to be estimated.

(1) Time Value

Time value of vehicle users and passengers is estimated based on the aforementioned assumption and tabulated with the composition ration of reach trip purpose to the total trips as shown in Table 1.9.1.

Table 1.9.1 Time Value Factor and Composition Ration by Trip Purpose

Trip Purpose (I)	Time Value Factor (Pi)	Composition Ratio (Ti)
Business	100%	11.0%
To work	50%	18.6%
To home	50%	42.5%
To school	No Value	11.6%
Private	No value	16.3%

Therefore : Pi * Ti = 41.25%

Table 1.9.2 Time Value

Year 2000	Year 2010
19.3	25.9

(Bath/hour/Person)

(2) Vehicle operating cost (VOC)

VOC are the major input to the estimate of the Project benefit. The representative vehicles which are classified and analyzed economic evaluation are the following types :

1) Motorcycle
2) Private car
3) Light bus
4) Medium bus
5) Heavy bus
6) Light truck
7) Medium truck
8) Heavy truck
9) Taxi

Vehicle operating costs consists of two components which are :

1) Running Costs
2) Fixed Costs

To get the running cost per vehicle type simply add the fuel cost, lubricant cost tire cost, maintenance and repair costs and depreciation cost of each vehicle type Basic fixed cost is total fixed cost less insurance cost multiplied by the reduction factor for commercial use and fleet reduction factor. To get the total fixed cost, just add the time related depreciation cost, opportunity cost of capital, crew cost, overhead, taxes and licenses cost and insurance cost result of the total vehicle operating cost by vehicle type are shown in Fig. 1.9.1.

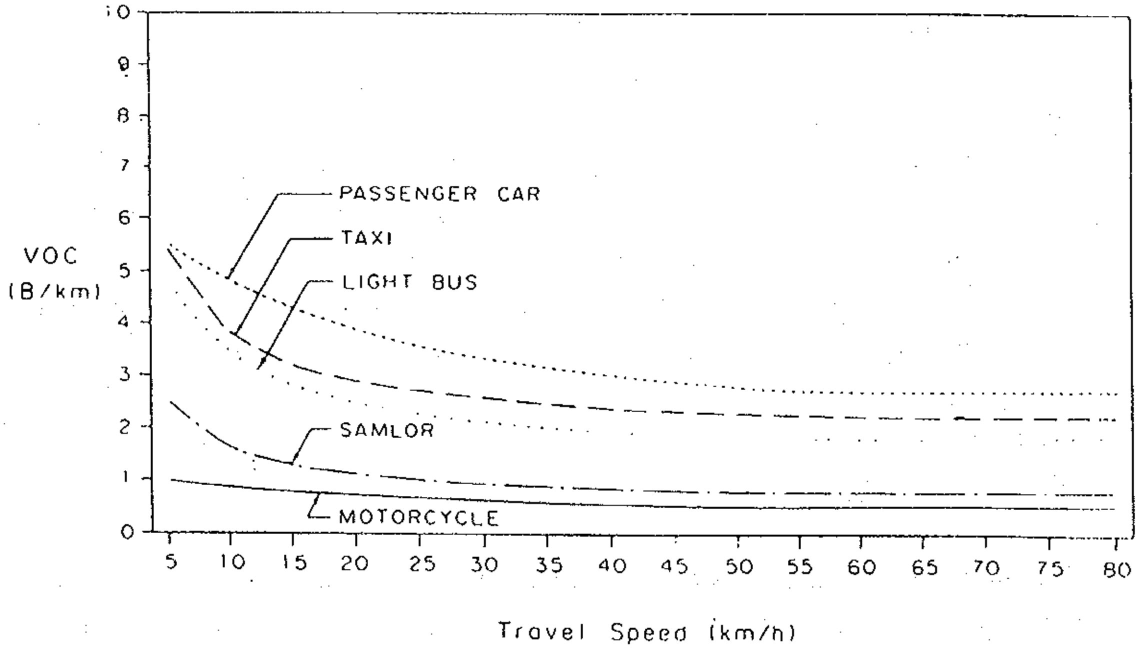
(3) Rail transit operating cost

The rail transit operating costs are composed of fixed costs and variable costs. The former is proportionate to the route lengths operated and the latter to the passengers transported.

The fixed and variable costs include the following items, respectively :

1) Fixed Costs

1. Initial expatriate management service
2. Personnel cost for general management
3. Maintenance cost for track and structure
   - 3-1 Building and machinery
   - 3-2 Guideway
   - 3-3 Signal and Communication
   - 3-4 Stations



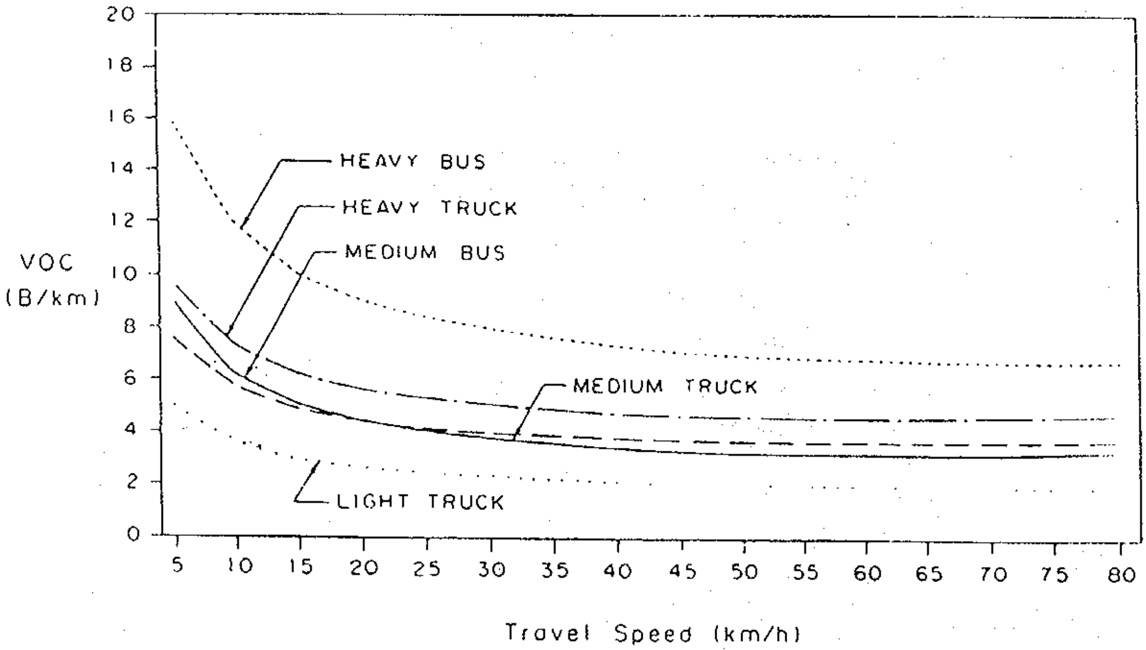


Fig. 1.9.1 Vehicle Operating Cost (1996)

2) Variable Cost

1. Personal cost for administration
2. Personal cost for operation
3. Power cot
4. Workshop / Car house
5. Depreciation and Interest of car

(4) Time Cost

Time cost is calculated using the family income approach method with the following assumptions :

a. Travelers will be willing to pay in order to save travel time

b. The traveler's value of travel time is a function of his personal income

c. The traveler's value of travel time is a function of his travel purpose

Time cost of each type of vehicle is calculated by the following formula :

$$Cj = Nj * Ij * \sum Ti * Pi$$

where

Cj	:	Time cost of vehicle "j"
Nj	:	Average occupancy of vehicle "j"
Ij	:	Hourly income of passenger of vehicle "j"
Pi	:	Tie value factor of trip purpose "I"

Then each item of the formula is determined as follows :

a. Average occupance (Ni)
- Private Car : 1.6 Passenger/pcu
- Public vehicle : 12.25 Passenger/pcu

b. Hourly income (Ij)
The Hourly income is calculated by the annual income of families and annual working hours.

c. Time value of vehicles
See 1.9.2.

1.9.3 Estimation Cost

Cost used in economic evaluation must be the economic cost. That is all taxes (sales tax or value added tax and commodity tax) and import duties must be removed. Cost components cover :

- Investment cost
- Maintenance cost

Routine and periodic maintenance costs are taken into consideration. It is assumed that periodic maintenance will be conducted every year.

- Land acquisition costs
- Operation costs

The following costs are incorporated into the operation costs in order to be able to operate the railway transport.

- personnel;
- telecommunications;
- insurance;
- water and electricity

The economic rate is the opportunity cost of capital to society as a whole and has a value for Thailand of approximately 12 percent.

Economic life reflects the actual period of time when the cost of maintaining as assets is greater than the cost of replacing it.

1.9.4 Economic Indicators

Economic indicators analyzed for the evaluation of this project, include : Internal Rate of Return (IRR), Net Present Value (NPV), and Benefit-Cost Ratio (B/C).

- Internal rate of Return

  IRR is defined as the discount rate at which the present values of the benefit and cost streams are equal. It is widely used by various development organizations in assessing different development / improvement alternatives. In Thailand, a project which can be recommended for implementation must have IRR at least 12 percent.

- Net Present Value (NPV)

  NPV is calculated by subtracting the present value of cost from the present value of benefit

- Benefit-Cost Ratio (B/C)

  B/C is the ratio of the present benefit to the present cost shown below :

$$\text{Benefit-Cost Ratio} = \frac{B}{C}$$

$$B = \sum_{i=1}^{n} \frac{bi}{(1+r)i}$$

$$C = \sum_{i=1}^{n} \frac{Ci}{(1+r)i}$$

Where

Bt = benefit in the year
Ct = cost in the year t;
i = discount rate, percent; and
T = analysis period, years

1.9.5 Results of Economic Evaluation

In conducting the economic evaluation, the following assumptions were used

(1) Railway investment schedule follows Table 1.8.1

(2) Urban development schedule follows Fig. 1.1.9. The number of available houses is assumed to be the total number of new project houses divided by each project years. Occupation rate of developed residence is assumed to be 100%.

Alternatives are shown in Table 1.9.3.

Table 1.9.3 Alternatives

Case A	:	Base case; Minimum maintenance
Case B	:	Railway improvement
Case C	:	Railway improvement + Feeder traveling time - 30%
Case D	:	Case C + Feeder fare - 30%

(3) Results of economic evaluation

Fig. 1.9.2 shows EIRR of the planned project for SRT by line. Each results shows the great economic impact by urban develop project on railway. All projects for each line show national wide enough economic effects, while final decision of selecting a project for feasibility study should be well examined in consideration with cost of project, and financial scheme and political aspect.

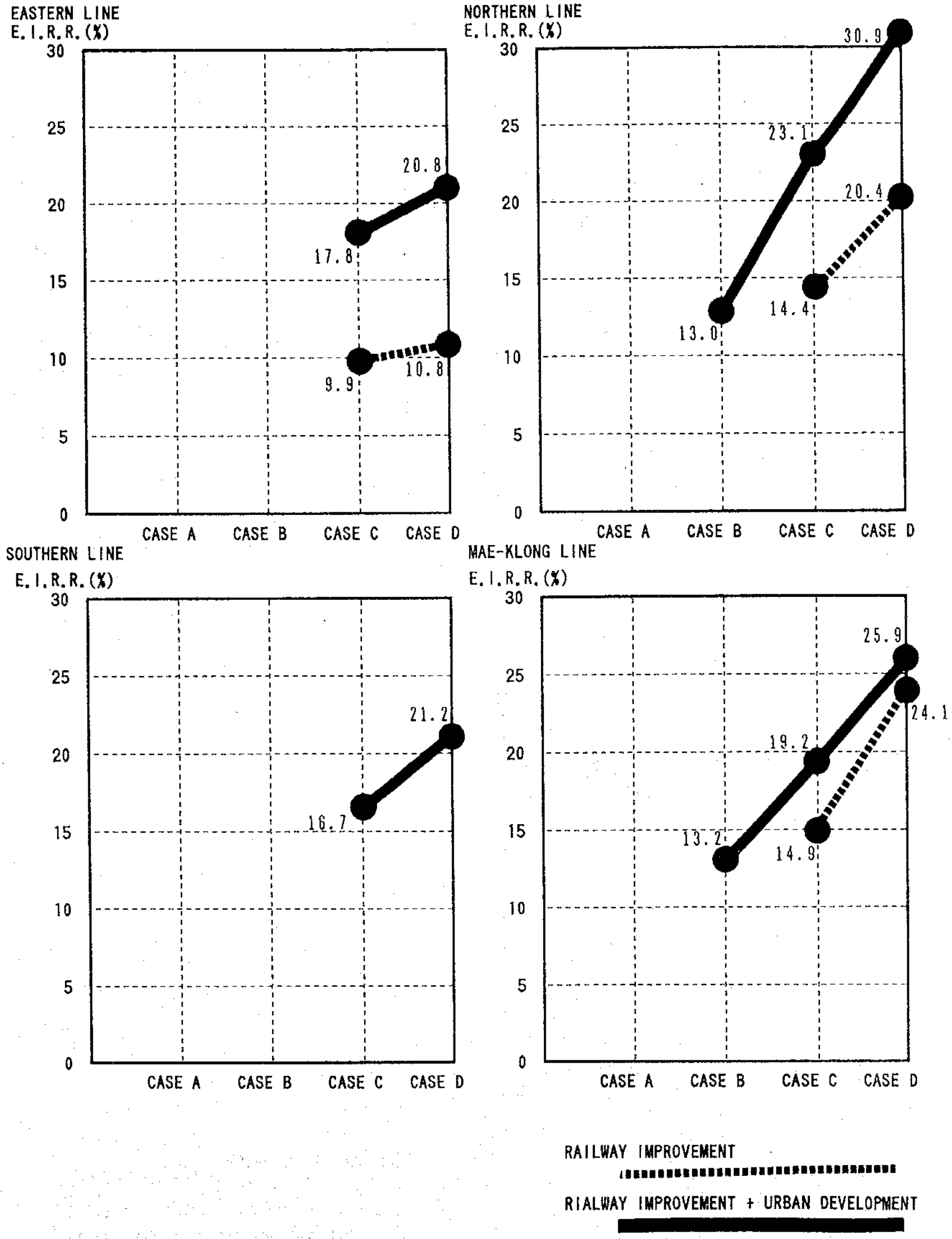


Fig. 1.9.2 Economic Evaluation : Commuter

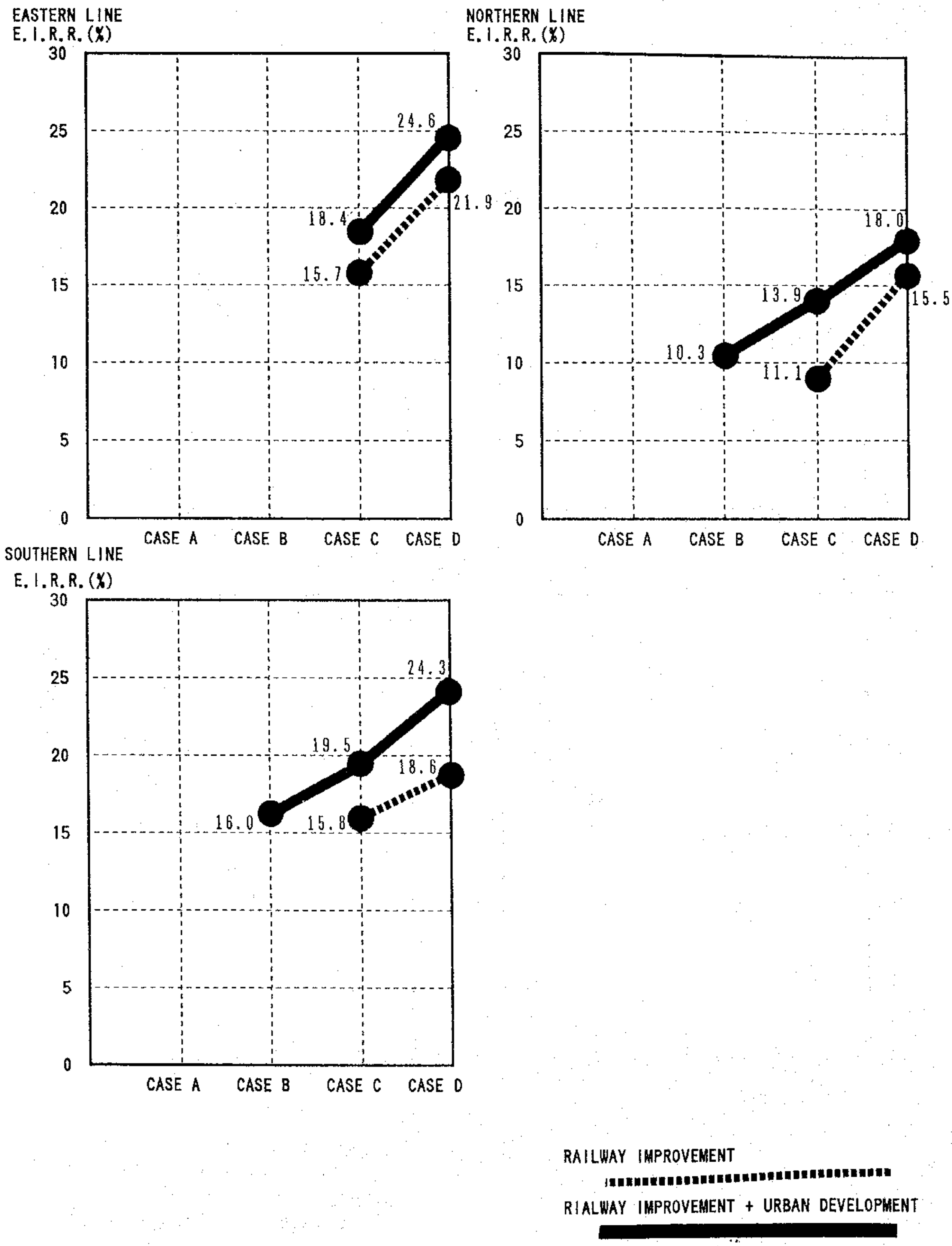


Fig. 1.9.3 Economic Evaluation: Medium Distance