Table 4.2.5 Track Capacity (Approximate value)

Section	Track capacity (number of trains)		Number of trains		
	At present	1996/97	At present	1996/97	2016/17
(Double track)					
TGL - YTG (9.3 km)	91	138	38	62	97
PEGU - PAG (17.3 km)	47	84	18	34	68
(Single track)					
TNDG - TGO (6.8 km)	41	73	18	34	68
SMN - TAB (11.7 km)	32	57	14	18	42

Note: The above number of trains is as per Figs. 4.3.1 and 4.3.2 in Chapter 4-3.

Source: Study Team

4-3 Train Operation Plan

4-3-1 Basic Concepts for Setting up the Train Diagram

The basic concepts for setting up the train diagram are as follows:

(1) Passenger trains

a) The number of scheduled trains and their operating sections will be determined from the traffic demand by section.

b) The types of trains will remain the same as at present.

- Express trains
- Ordinary trains
- Local trains

c) The sections of train operation will be based on the present practice.

d) The train operation time zone for the setting up the passenger train schedule, is from 4:00 to 22:00 o'clock at major terminals.

e) The number of passenger trains will be the same in both directions.

f) For each section, the number of scheduled local passenger trains (which stop at every station), and the number of ordinary passenger trains which provide rapid service, will be the same.

g) The boarding rate for passenger trains will be basically set at 110 percent for express trains, and 120 percent for ordinary and local trains, at the peak traffic section.

h) DF1600 type diesel locomotives will be used for express passenger trains, and for ordinary passenger trains, considering the performance of these diesel locomotives, and speeding-up of trains. DF1200-type diesel locomotives will be used for local passenger trains.

i) Train formation of express passenger trains will be reduced to 11 cars, from the 14 cars (average) at present, considering the tractive force and the speed increase. The train formation of other types of trains will be based on the present formations.

j) Stopping stations for passenger trains will be based on the present schedule.

(2) Freight trains

a) Concerning freight trains, it is necessary not only to consider transport demand, but also to examine the future form of transport, the modernization of work in the marshalling yards, etc. In this report, however, freight trains will be determined as needed for transport demand on the Mandalay line.

b) The up and down traffic volumes by section shows some difference, but the number of trains in both directions will be set at the same, considering the balance in movement of wagons.

c) Train formation will be made up of bogie wagons with maximum speed of 56 km/h (35 mph).

d) Loading capacity of freight trains will be about 400 tons (a load factor of 75 percent), and gross trailing load will be 800 tons to keep a balance between loaded and empty wagons. DF1600 type locomotives will be used in view of their capacities.

4-3-2 Premises

Premises for setting up the train diagram are as shown below.

(1) Train formation:

a) Express passenger train

DF1600 + Upper x 2 + Ordinary x 8 + Brake Van

b) Ordinary passenger train

DF1600 + Upper x 2 + Ordinary x 9 + Luggage Van x 2 + Brake Van

c) Local passenger train

DF1200 + Ordinary x 4 + Luggage Van x 2 + Brake Van

d) Freight train

DF1600 + Wagon x 23 + Rest Van + Brake Van

(2) Transport capacity of train:

a) Passenger train:

Passenger coach: Upper class = 30 persons
Ordinary class = 62 persons

Express passenger train = 612 persons
(When boarding rate is 110 percent)

Ordinary passenger train = 742 persons
(When boarding rate is 120 percent)

Local passenger train = 298 persons
(When boarding rate is 120 percent)

b) Freight train

Gross trailing load 793 tons = 396 tons (load) + 15 tons (Tare) x 16
+ 52 tons (Rest Van + Brake Van)
+ 15 tons x 7 (Empty wagons)

(3) Running speed of trains

a) Maximum speed

Passenger train: 80 km/h (50 mph)

Freight train : 56 km/h (35 mph)

b) Maximum permissible speed through turnout

Straight side : 72 km/h (45 mph)

Turnout side : 32 km/h (20 mph)

(4) Stopping time

Express passenger train : 3 minutes (at 7 station stops)

Ordinary passenger train: 4 minutes (at 32 station stops)

Local passenger train : 1 minute (almost every station)

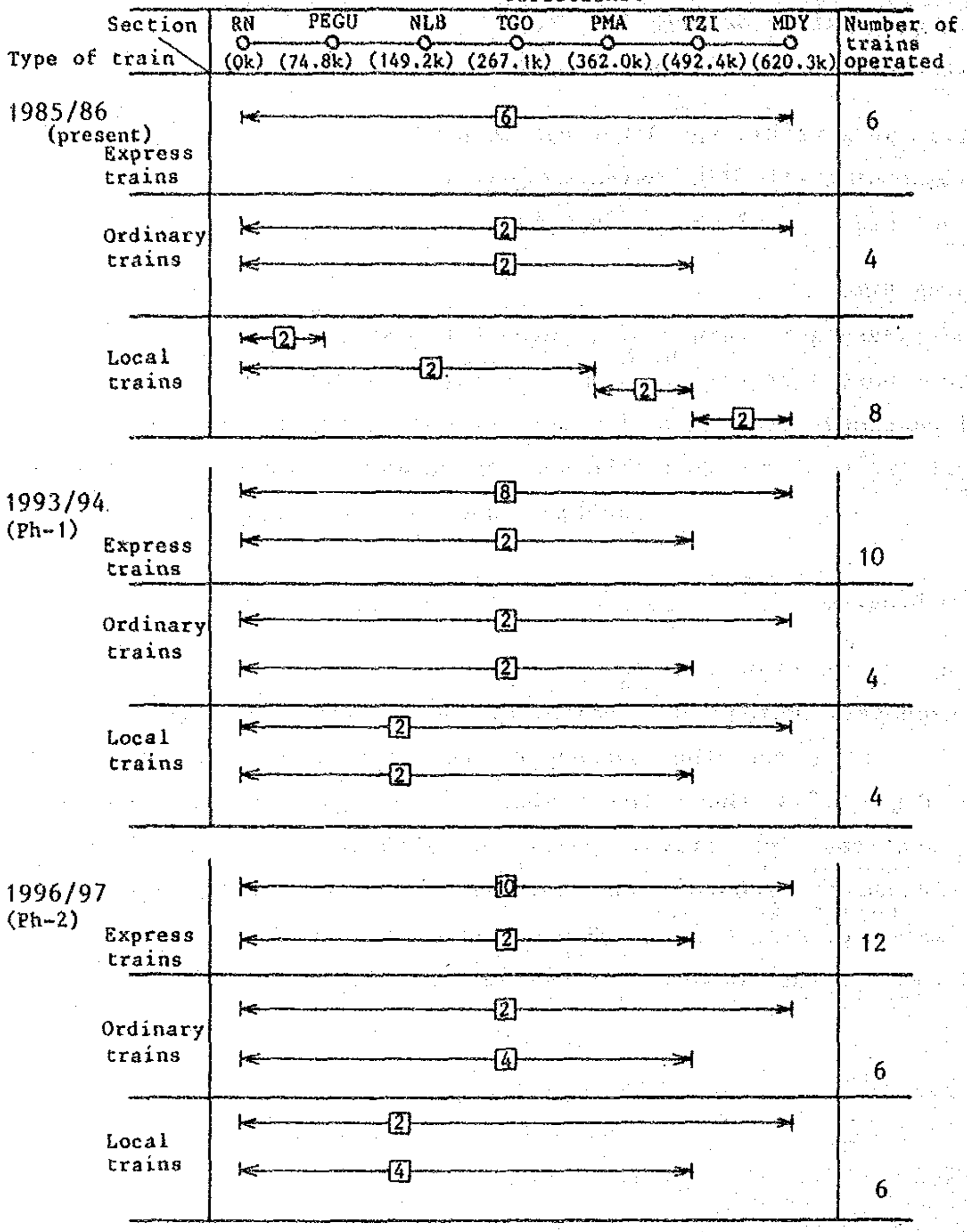
Freight train : The same as at present (both for number of stations and for stopping time)

4-3-3 Train Diagram

(1) Setting of number of trains

The necessary number of trains is calculated from the transport capacity per train and the passenger and freight traffic volume by section. Fig. 4.3.1 shows the number of passenger trains and their operation sections for fiscal years of 1985/86, 1993/94 (Phase-1), 1996/1997 (Phase-2), 2005/06, and 2016/17. The same data for freight trains is shown in Fig. 4.3.2. The summary table of the transport plan, at present and for the future, is shown in Table 4.3.1.

Explanatory note:
☐ is the total of the number of trains operated, in both up and down directions.



Note: In both Figs. 4.3.1 and 4.3.2, the number of trains per section is fixed, but the above number of trains may vary depending on the time zone at which trains are to be set.

Fig. 4.3.1 Operating Sections and Number of Passenger Trains (1)

Source: Study Team

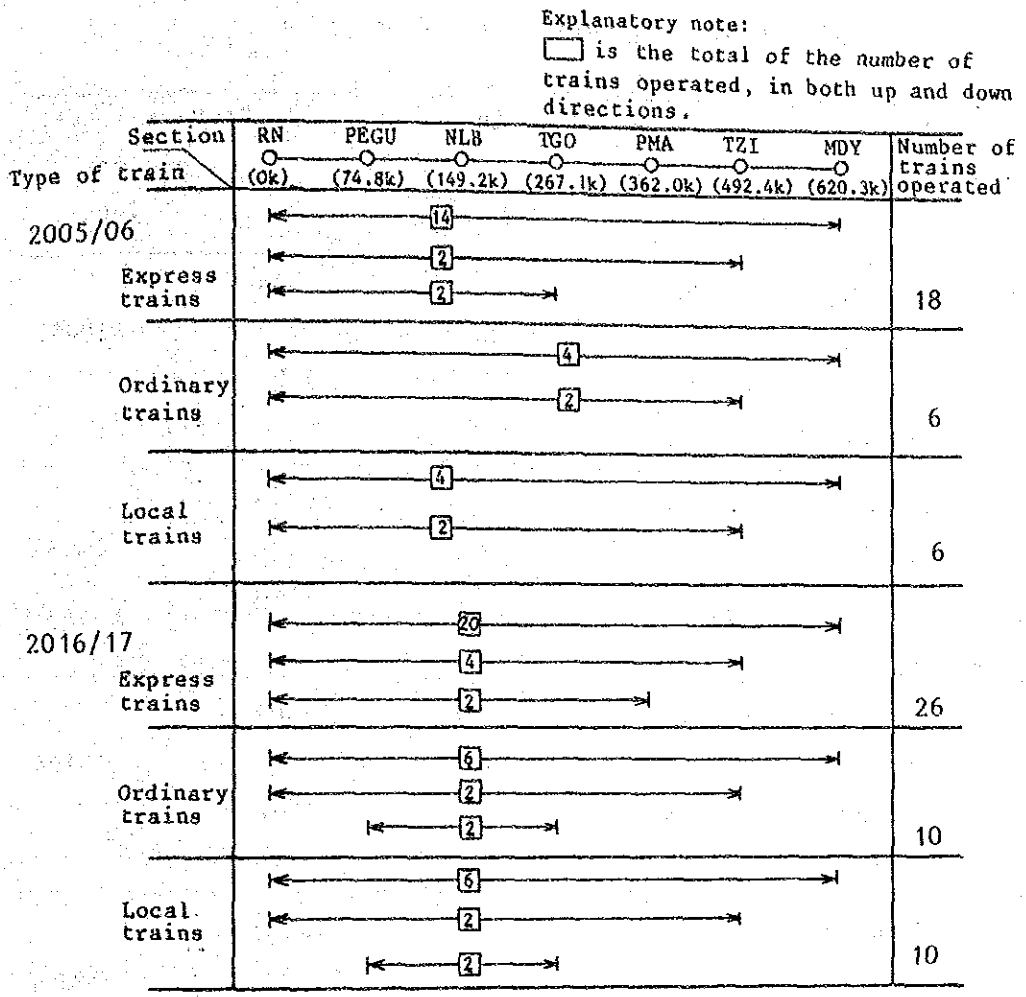


Fig. 4.3.1 Operating Sections and Number of Passenger Trains (2)

Source: Study Team

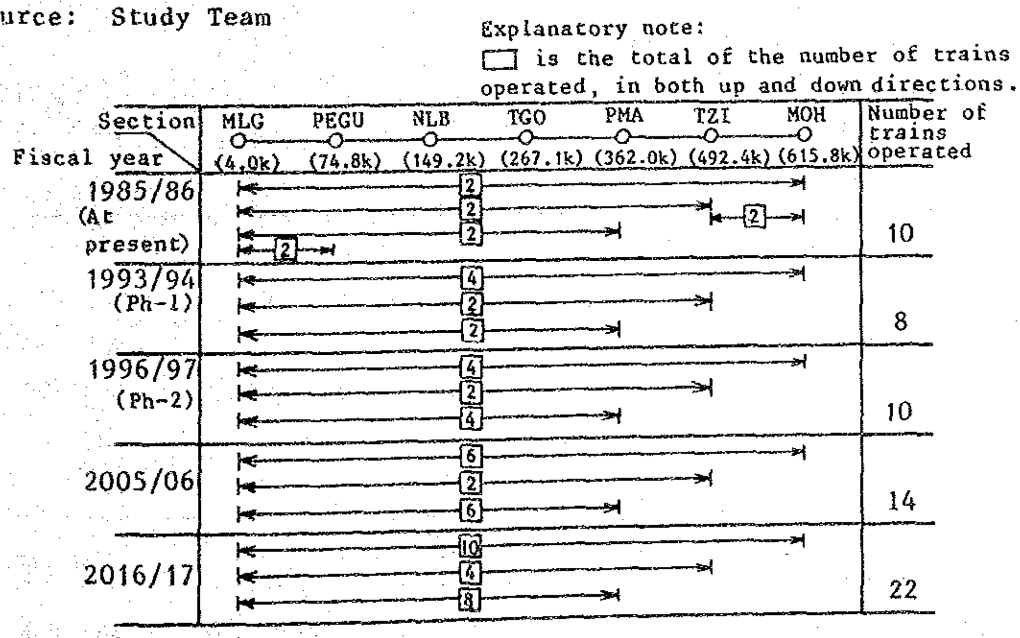


Fig. 4.3.2 Operating Sections and Number of Freight Trains

Source: Study Team

Table 4.3.1 Summary of Transport Plan

Fiscal Year	Type of train	Number of trains per day	Total	Train-kilometers per day	Total
1985/86 (at present)	Passenger trains	18	28	7337	10642
	Freight trains	10		3305	
1993/94 (Ph-1)	Passenger trains	18	26	10398	14538
	Freight trains	8		4140	
1996/97 (Ph-2)	Passenger trains	24	34	13608	18464
	Freight trains	10		4856	
2005/06	Passenger trains	30	44	16601	23397
	Freight trains	14		6796	
2016/17	Passenger trains	46	68	25282	36218
	Freight trains	22		10936	

Source: Study Team

(2) Train diagram

Train diagrams for 1996/97 (Phase-2) and 2016/17 after the facilities improvement were drawn on the basis of concepts and premises of the train diagram setting. These diagrams are shown in Appendix 4.3.(1).

In the planned diagram for 1996/97 (Phase-2), the operating section and number of trains are set to be the same on up and down for all passenger trains (express, ordinary and local trains) and freight trains. Day time and night time express trains are set in the diagram in the first place, and then ordinary and local passenger trains are set in consideration of their operating sections and time zones. Next, the freight trains are set mainly in the night time zone.

In the train diagram for 2016/17, only the passenger train diagram on the Mandalay line is shown, because there are many uncertain factors in the transport form and system of freight trains, and on the Martaban and Rangoon suburban lines.

Table 4.3.2 shows the scheduled times of express passenger trains between major stations. The details on calculation of the scheduled times are shown in Appendix 4.3.(2).

Table 4.3.2 Scheduled Times between Major Stations (Express Passenger Train)

Section	Distance (km)	Scheduled Time	Remarks
RN-PEGU	75	1 hr : 14 min	
PEGU-PYU	141	2 : 13	1. Stops at 7 stations
PYU-TGO	51	0 : 51	2. 3-minute stop at each station
TGO-PMA	95	1 : 25	
PMA-PWW	100	1 : 33	3. Excluding stopping time
PWW-TZI	30	0 : 26	
TZI-TEW	26	0 : 22	
TEW-MDY	102	1 : 35	
RN-MDY	620	10 : 00	Including stopping time

Source: Study Team

4-4 Rolling Stock Plan

4-4-1 Present State of Rolling Stock

Table 4.4.1 shows the number of rolling stock (not including reserve stock) to accommodate the present train diagram.

Table 4.4.1 Number of Rolling Stock in Actual Service

	Type of train	Locomotive	Coach	Wagon
Passenger trains	Express trains	6	76	-
	Ordinary trains	4	36	-
	Local trains	5	28	-
Freight trains		15	-	296
Total		30	130*	296

Note: 1. * is the figure excluding mail, L/V, B/V.

2. Rolling stock does not include reserve stock and those being repaired.

Source: BRC

According to the Report on the long-term modernization programme, as shown in Table 4.4.2, the number of rolling stock in actual service on the Mandalay line is much larger than that in the above table. However, the present train service suspension indicates that the actual number of rolling stock ready for service and working efficiency shown in Table 4.4.2 are likely to become less, because of the deterioration of rolling stock, and also because of an increase in the number of rolling stock awaiting repair due to the shortage of spare parts.

Table 4.4.2 Present Number of Rolling Stocks for the Mandalay Line

	Number of rolling stock distributed	Number of rolling stock ready for service	Working Efficiency (percent)
Locomotive	89	51	57
Coach	254	178	70
Wagon	5743	* 4422	77

Note: 1. Figures extracted from the Report on the Long-term Modernization Programme.

2. * Figure estimated from present train-kilometre.

Source: BRC

The short supply of parts for the diesel locomotives which depend upon parts imported from overseas for more than 90 percent, has become serious.

4-4-2 Amount of Rolling Stock Required

Table 4.4.3 shows the number of rolling stock required, calculated for the future transport plan, based on train-kilometre per day and car-kilometre per day.

Table 4.4.3 Number of Rolling Stock Required

Rolling Stock / Fiscal year	Locomotive			Coach	Wagon*
	DF1600	DF1200	Total		
1993/94 (Ph-1)	51	9	60	211	3,538
1996/97 (Ph-2)	55	13	68	254	3,729
2005/06	75	15	90	325	5,222
2016/17	117	20	137	466	8,408

Note: 1. The DF1600 is used for express, ordinary passenger trains, and for freight trains.

2. The DF1200 is used for local passenger trains.

3. * means the number equivalent to bogie car.

4. L/V, B/V and R/V, B/V are not included in the number of Coach and Wagon, respectively.

5. The number includes reserve stocks (30 percent increase).

Source: BRC and Study Team

When the number, as well as quality, of rolling stock required in the future should exceed that of existing rolling stock, the shortage will be purchased under the revised BRC rolling stock modernization plan. In this plan, DF-1600 type locomotives and bogie wagons should be introduced to realize the effects of the shortening in scheduled time accompanying the improvement of ground facilities.

4-4-3 Crew and Maintenance Personnel

The number of crew and maintenance personnel required is as shown in Table 4.4.4.

Table 4.4.4 Number of Crew and Maintenance Personnel

Fiscal year	Crew	Maintenance Personnel	Remarks
1985/86	330	1123	1. The crew includes a driver, co-driver and guard.
1993/94 (ph-1)	355	872	2. Maintenance personnel is for Loco, PC and FC, for sheds only (excluding workshops)
1996/97 (ph-2)	354	1008	
2005/06	461	1324	
2016/17	725	1973	

Source: BRC

CHAPTER 5 FACILITY IMPROVEMENT PLAN

CHAPTER 5 FACILITY IMPROVEMENT PLAN

5-1 Train Operation Control

5-1-1 New Train Control System

Train operation control between Rangoon and Mandalay is conducted by five control offices, namely, Mandalay, Thazi, Toungoo, Pegu, and suburban control offices. At these offices, the train operation control work is carried out by collecting information and issuing instructions necessary for the train operation through communication by telephones with each station, locomotive shed, marshaling yard, etc. under their jurisdiction.

A speedy and accurate control system will be required in the future for operation of trains at higher speed and higher density. Prompt actions have to be taken by controllers to communicate with the organizations concerned and to prevent secondary accidents, based on a higher level of judgment, especially on the occasion of an accident or a disaster.

To ensure the high level judgment of controller, the new train control system consists of two tiers, i.e., central control office and divisional control offices, as shown in Fig. 5.1.1. The role of each control office will be clearly defined since the management of railway transport is complicated and extends over a wide range.

The central control office monitors train operation to maintain safe and smooth train operation on all routes and gives directives based on overall judgment.

The divisional control office is designed to enforce precise operation control in its own section based on the directives of the central control office.

Table 5.1.1 shows the main work of each control.

Table 5.1.1 Main Work of Each Control

Name	Work
Train control	• Monitoring train operation including the location and route of trains • Providing necessary information and instructions to each station and train
Passenger control	• Making various transport arrangements for comfortable transport • Providing information and substitute transport in the case of an accident
Freight control	• Collecting wagon information including the location and utilization of wagons • Instructions on formation of freight trains and arrangement of wagons
Rolling stock control	• Grasping the location of locomotives and carriages and their utilization • Control of operation of locomotives and carriages
Facilities control	• Monitoring the condition of facilities, mainly the operational safety facilities • Giving instructions for preservation of facilities in case of abnormalities

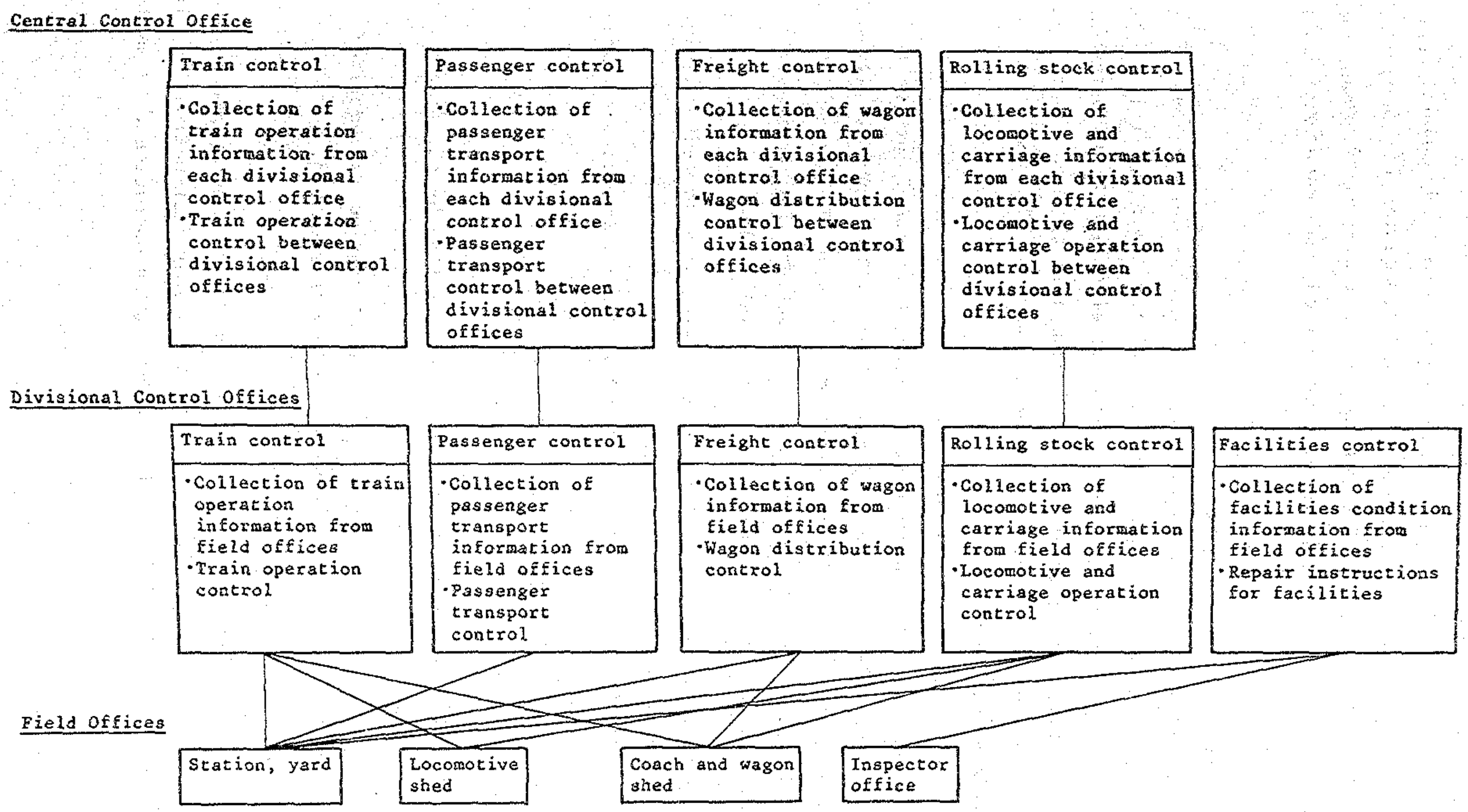


Fig. 5.1.1 New Control System

5-1-2 Improvement Plan for New Control System

In the new control system, system improvement and modernization are to be achieved by the introduction of various communication facilities to ensure an efficient train control system. Table 5.1.2 shows the control facilities in the central control office and each divisional control office.

(1) Train operation display system

The conventional method of gaining operational information merely by telephone from each station is not sufficient for train control in the future to carry out punctual, speedy, safe and efficient train operation for about two times the current number of scheduled trains. Therefore, the train operation display system will be introduced. The unit will

1) unify the train control work
2) simplify the train control work

and collect real-time operational information required for the train control work and display it to the controller at the control offices. Then the controller can monitor the location of trains in his area at all times and, can issue timely and suitable instructions for train control even in emergency situations such as an operational accident.

The specific information needed for train operation control work is:

1) Track layout of all relevant railway lines
2) Conditions of wayside equipment including track circuits and signals
3) Train number and train location
4) Operating direction of trains
5) Block condition

The information at each station will be transmitted by the electronic token block system.

Time of train departure and arrival at each station is memorized in the display unit and it is recorded by printer, when required.

(2) Control telephone system

The controller has to understand train operation conditions at all times and, should a train delay occur, give the proper instructions to the related stations and organizations to recover smooth operation as soon as possible.

Table 5.1.2 Control Facilities

Type of control	Telecommunication Facilities		Signalling Facilities	
	Plan A	Plan B	Plan A	Plan B
Central control office				
Train control	Control telephone system Train radio system	Control telephone system		
Passenger control	Control telephone system Train radio system	Control telephone system		
Freight control	Control telephone system Wagon data processor system	Control telephone system		
Rolling stock control	Control telephone system	Same as Plan A		
Divisional control office				
Train control	Control telephone system Train radio system	Control telephone system	Train operation display system	Same as Plan A
Passenger control	Control telephone system Train radio system	Control telephone system		
Freight control	Control telephone system Wagon data processor system	Control telephone system		
Rolling stock control	Control telephone system	Same as Plan A		
Facility control	Control telephone system	Same as Plan A	Train operation display system	

For this purpose, the Control Telephone System by which the controller can call each station separately, simultaneously or in a group will be installed for the exchange of operational information between the controller and the station master.

(3) Train radio system

With the increase in the train speed and the number of scheduled trains, effective train operation, safe transport and improved passenger transport service will become increasingly required. For these purposes, the train radio system, indispensable for emergency communication among the crew, controller, and station staff in case of any disorder, will be introduced.

(4) Wagon data processor system

The existing wagon distribution work is divided into two stages, one at the head office and the other at divisional offices. Each office has the required authority for the wagon distribution, and gives wagon distribution instructions, based on the information for each type of wagon and condition of wagon collected at the head office by telephone from each station through divisional offices.

To further improve the efficiency of the wagon control and distribution, wagon data processor system will be a useful means.

The main purposes of the system are:

1) Unified control of wagon information to achieve efficient wagon operation
2) Reduction of staff
3) Improved customer service

The main functions of the system are to assemble and assort wagon information and make an optimum wagon utilization plan. Namely, the system collects individual wagon information such as the location on a route, kind, condition, destination, train links and wagon reservations at the central control office through the station and divisional control offices.

At the central control office, the wagon distribution plan is made by a personal computer on the basis of this information and given to each divisional control office.

Each divisional control office makes a detailed wagon distribution plan for the wagons within its area, and the controller gives each station the wagon distribution instruction by telephone.

(5) Monitoring the condition of operational safety facilities

A large number of high quality facilities will be newly installed to improve and modernize the railway facilities by this project. This makes the facilities monitoring work increasingly important for safety. Therefore, the signals and telecommunication facilities monitoring function will be added to the train operation display unit.

To be specific, the following information will be monitored:

1) Centralized monitoring information

Faulty throwing of switches, irregular voltage drop of track circuits, etc.

2) Information on condition of station equipment

Condition of equipment related to safety and information transmission

When facility trouble occurs, the display unit displays the name of equipment in trouble, trouble condition and time of occurrence, etc.

5-2 Track

5-2-1 Improvement Plan

(1) Present condition of track

The present condition of the track between Rangoon and Mandalay is as follows:

1) Rail

Most of the rails are more than forty years old with batter at ends, and continuous corrugation and joint drop are observed.

2) Sleeper

Most of the sleepers are of wood with short life. However, because the sleepers are not easily obtained, the rate of replacement is very low, at 4 percent annual average. Many dog spikes are floating due to their poor supporting force. The rate of defective sleepers due to corrosion is approximately 50 percent.

3) Ballast

In most sections, the thickness of ballast is insufficient, and the sleepers are exposed in many places, which is the causes of frequent irregularity in alignment of track.

4) Turnout

Various parts of turnout are loosened and the crossings are worn out, which is one of the causes of train speed restrictions.

(2) Track improvement plan

Based on the present condition of track explained in the preceding section, the track improvement will be promoted mainly in the following points.

- Replacement of old rails and introduction of long-welded rails
- Adoption of PC sleepers
- Increase in ballast
- Replacement of worn-out or loosened turnouts.

In addition, unused turnouts are removed, cant compensated, and transition curves extended and the roadbed drains improved.

1) Rail replacement

The rail replacement is carried out mainly for the old and worn-out rails. In this case, long-welded rail is introduced as much as possible.

Having no rail joint, which is the weakest point of track, the long-welded rail causes less track irregularities, providing very smooth train operation and reducing track maintenance cost.

The places where the long-welded rail can hardly be laid are the track on the bridges longer than 25 metres, or the sharply curved track whose radius is less than 600 metres.

From the viewpoint of future maintenance and prevention of rail deformation accident, the long-welded rail had better not be used at the back of abutments of bridges or before and after the level crossings, since track irregularities are liable to occur at such places.

Furthermore, the ordinary rails had better be used at the turnouts and the tracks between them because of the short track and lower train speed compared with other sections.

(a) Long-welded rail

The length of one long-welded rail is ordinarily not limited. However, bridges, sharp curves and turnouts at stations restrict the length of the rail. If laying work of long-welded rail and the repair work in case of track faults are considered, the optimum length of one long-welded rail would be approximately one mile (1.6 km).

(b) Ordinary rail

The laying of ordinary rail whose standard length is 39 feet (approximately 11.9 metres) requires a large number of rail joints. On the premise of minimizing the number of rail joints, it is concluded that the optimum rail length is 39 feet x 3 pieces (approx. 35.7 m) in consideration of proper rail joint expansion space and rail expansion according to the temperature change.

Thus, in using the ordinary rails, it is a rule to lay three welded rails of standard length. For the rail expansion space, in this case, refer to 5-2-2, "Standard rail expansion space".

For the rail types to be used, refer to 5-2-2, "Standard track materials".

2) Sleeper replacement

On replacing sleepers, use the PC sleepers as much as possible except in the track where the adoption of PC sleeper is difficult such as on bridges, at level crossings, turnouts and curved track whose radius is less than 600 metres.

Wooden sleepers are laid where the adoption of PC sleepers is difficult, or to temporarily reduce the rate of defective sleepers until the completion of the track improvement work.

Defective bridge sleepers are replaced, when the hook bolts are repaired and sleeper splicing materials are installed in order to maintain a constant space between sleepers.

3) Increase in ballast

In most sections, the ballast is insufficient. It has to be increased throughout all sections to produce the specified ballast cross section.

The ballast cross section should have the following standard dimensions depending on the track structure.

(a) Long-welded rail section

- below sleeper: 200 mm or more
- width of ballast shoulder: 400 mm or more
- gradient of ballast slope: 1:1.5

(b) Section of PC sleepers under ordinary rails

- below sleeper: 200 mm or more
- width of ballast shoulder: 300 mm or more
- gradient of ballast slope: 1:1

(c) Section of wooden sleepers

As per existing standard cross section

- below sleeper: 200 mm or more
- width of ballast shoulder: 300 mm or more
- gradient of ballast slope: 1:1

4) Turnout replacement

If a turnout is totally worn out or loosened, replace it wholly. For partial abrasion or looseness at crossing, etc., replace the part only.

Prior to the turnout replacement, study should be made on the removal of unused or seldom-used turnouts to make the track straight.

The turnouts to be removed are the following ones on the main track.

- turnout to sidetrack
- turnout for crossover between main tracks

In this case, one of the crossover turnouts on the Mandalay or Rangoon side is removed.

The turnout removal plan should be studied on the basis of Appendix 5.2.

5) Improvement of cant and transition curve

Improvement will be made where cant and transition curve length become insufficient to the increased train speed. As for the magnitude of cant and transition curve length, study should be made based on the specifications in Section 5-2-2.

The improvement of cant and extension of transition curve length are to be made when works to increase the ballast are carried out.

For the improvement of radius of curves, on the other hand, a fairly large sum of investment is required since most of such curved track are on bridges or in the embanked sections. On the single track line, therefore, it is desirable to carry out the improvement at the time of double tracking construction in future.

6) Roadbed drain improvement

In the section between Rangoon and Toungoo, the station yards are flooded in the rainy season, so that drains are to be installed between up and down lines. At the stations without turnouts, however, the drains will not be installed.

(3) Alternative plan for improvement

For the track improvement, the alternative plans as shown in Table 5.2.1 are drawn up in consideration of the cost and effect of the investment and improvement work capability.

1) Alternative Plan A

As many long-welded rails and PC sleepers as possible will be laid. PC sleepers will also be laid in the sections not subject to rail replacement.

2) Alternative Plan B

Laying of long-welded rails will be about 80 percent of the total length specified in Alternative Plan A, and PC sleeper laying will be limited in the sections where rails are to be replaced.

3) Alternative Plan C

Laying of long-welded rails will be about 70 percent of the total length specified in Alternative Plan A, and PC sleeper laying will be limited in the sections where long-welded rails are to be laid.

In the Rangoon - Pegu section, long-welded rails and PC sleepers will be laid to the maximum extent. This section will be treated in the same way in the three alternative plans.

When the alternative Plans A, B and C are compared, the section with long-welded rails, the number of PC sleepers and the quantity of ballast becomes smaller in the order of A, B, C, therefore, the amount of investment of alternative Plans B and C are smaller than Plan A by about 10 and 30 percent, respectively. The amount of rail welding work and the production of PC sleepers and ballast decrease in the order of A, B, C.

However, the maintenance costs after the improvement in alternative Plans B and C increase by about 10 percent and 40 percent, respectively, over that of alternative Plan A, because alternative Plans B and C have larger sections of joint rails and wooden sleepers.

The train speed aimed at in this project can be achieved in any of alternative Plans A, B or C.

Table 5.2.1 Alternative Plans for Improvement

Item	Unit	Alternative		
		Plan A	Plan B	Plan C
Rail replacement				
Long-welded rail	km	610	490	410
Ordinary rail	km	190	310	390
Sleeper replacement				
PC sleeper	1,000 pieces	1,410	1,180	700
Wooden sleeper	1,000 pieces	150	200	220
Bridge sleeper	1,000 pieces	8	8	8
Increase in ballast	1,000 m^3	630	590	530
Turnout replacement				
Total replacement	sets	160	160	160
Partial replacement	sets	150	150	150
Improvement of cant and transition curve	Places	*	*	*
Improvement of drains	Places	34	34	34

Note: * Study on the condition of each curve is necessary.

Source: Study Team

5-2-2 Standard of Track Structures

As to track improvement, the following are applied as the standard for track structures.

(1) Standard on track materials

1) Type of rail

The bearing capacity of track is rather small because of the maximum axle load of 13 tons and planned maximum speed of 50 miles/h. In this project, therefore, rail weighing 75 lb/y (37 kg/m) and BS-R type section is used.

(a) Common rail

The rail to be used for welding is an ordinary rail, i.e., not heat-treated, and without bolt holes.

(b) Heat-treated rail

a) For the outside rail at a curve whose radius is 600 metres or less, head-hardened rail is used.

b) For the joints, end-hardened rail is used.

2) Fastenings of rail

(a) For PC sleepers, coil spring type double elastic fastenings are used.

(b) For wooden sleepers, coil spring type fastenings or dog spikes are used.

3) PC sleeper

Refer to Chapter 6.

4) Wooden sleeper

For regular sleeper and turnout sleeper, the existing standards are used. For the joint sleeper at the section of PC sleeper, wooden sleepers for joint (300 x 140 x 1830 mm) are used.

5) Turnout

(a) The type of tongue rail is common tongue or spring tongue.

(b) The type of crossing is assemble crossing or manganese steel crossing.

(2) Standard of track structure

1) Placement of rail joints

Of the two placement methods of rail joints, opposite joints and alternate joints, the latter is not desirable because its structure is liable to cause track alignment and cross-level irregularities in opposite form which disturbs the running stability of train.

In principle, therefore, the rail joints are to be laid in the opposite way. However, on curves with a radius of less than 400 metres, where the rail length largely differs between the right and left rails, the joints can be laid alternately. In the opposite joints, the position of joints of both side rails should make a right angle with the centre line.

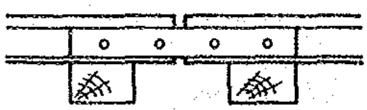
2) Joint supporting method

The general method of supporting joints is the suspended method or the supported method. Test results show that the supported method, in which the sleeper is laid just below the rail joints, has greater strength against the track breaking.

Therefore, the joint supporting methods to be applied are:

- Suspended method in wooden sleeper section
- Supported method in PC sleeper section, with wooden sleepers (300 x 140 x 1830 mm) just below the rail joints.

Fig. 5.2.1 shows the placement of sleepers at the joints.



Suspended method

Supported method

Fig. 5.2.1 Placement of Sleepers at the Joints

3) Setting of rail joint expansion space

Insufficient rail joint expansion space may cause accidents by rail deformation, and excessive space increases the impact force when the train passes which leads to greater joint drop, breakage of rail and fish plates as well as breakage of joint bolts.

In order to avoid such accidents, therefore, appropriate rail joint expansion space should be set, and where the space is apt to be changed by rail creeping, an appropriate measure for the prevention of creeping has to be taken. The rail joint expansion space varies depending on the rail temperature.

Fig. 5.2.2 shows the standard rail joint expansion space in the case of maximum rail temperature of 60°C and minimum temperature of +10°C.

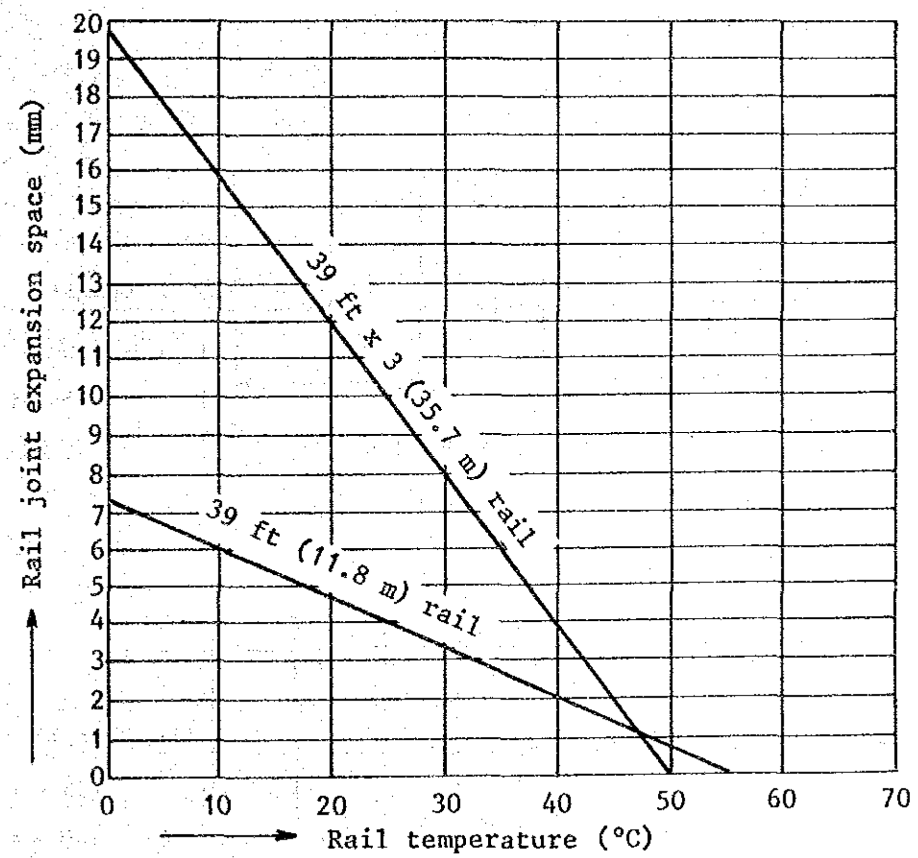


Fig. 5.2.2 Standard Rail Joint Expansion Space to be Set

Source: Study Team

4) Expansion switch setting

Refer to 5-6-1 "Standards on laying long-welded rail".

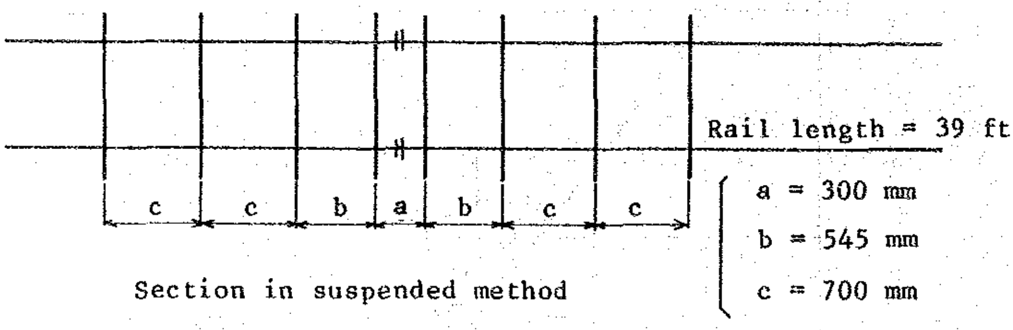
5) Placement of sleepers

(a) Number of sleepers to be laid

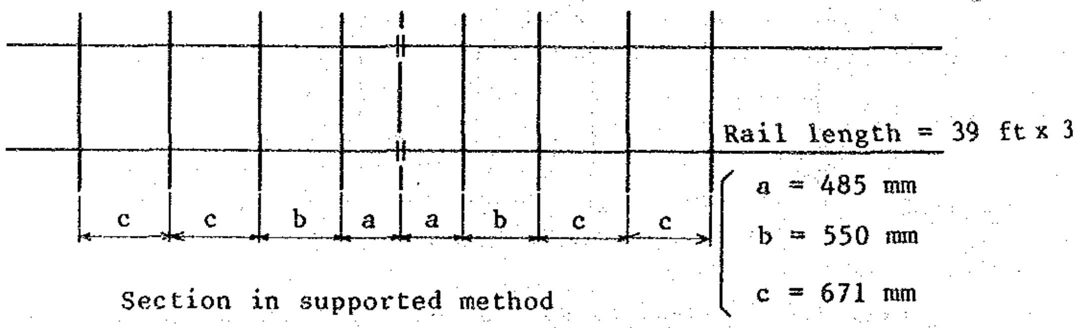
The number of sleepers to be laid on the main track should be more than 18 pieces per 39 feet (11.887 metres). In curve sections with a curve radius of less than 600 metres, two more pieces should be laid per 39 feet.

(b) Sleeper space at joints

At joints where the passing train has a larger impact force, smaller sleeper space is necessary to add supporting force. Fig. 5.2.3 shows the standard sleeper space.



Section in suspended method



Section in supported method

Fig. 5.2.3 Standard Sleeper Space

6) Ballast section

The ballast receives the train load and impact, and diffuses them to the road bed, providing the track with the required resisting force in both longitudinal and lateral directions. In order to preserve such ballast functions, the proper depth of ballast and the shape of its section have to be maintained at all times.

(a) Long-welded rail track

Compared with the jointed rail track, the long-welded rail track has larger axial force, and for that reason, the lateral resistance of ballast has to be increased. The shape of ballast cross section depends on the dimensions of sleeper, ballast thickness beneath the sleeper, width of ballast shoulder and gradient of ballast slope. Therefore, the width of ballast shoulder is to be increased and the ballast slope gradient of 1 : 1.5 is to be the standard. The standard ballast dimensions for long-welded rail track are shown in Table 5.2.2.

(b) Jointed rail track

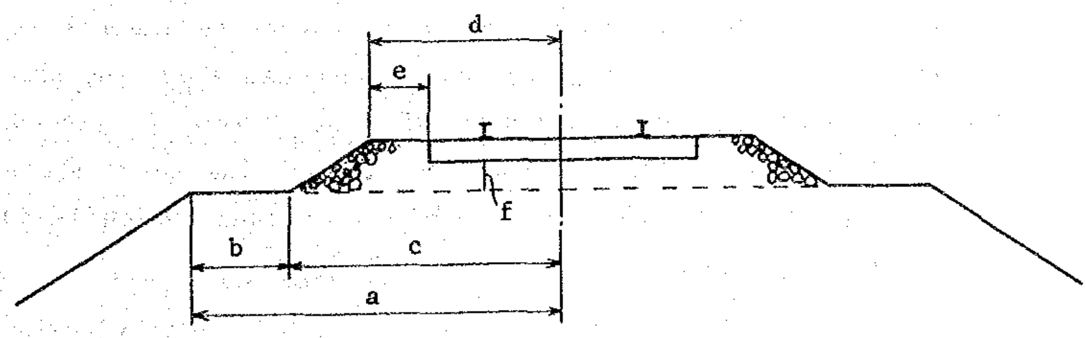
For the ballast cross section for jointed rail track, the existing standard will be applied.

Table 5.2.2 Basic Dimention for Ballast

(a) Straight section

(Unit: mm)

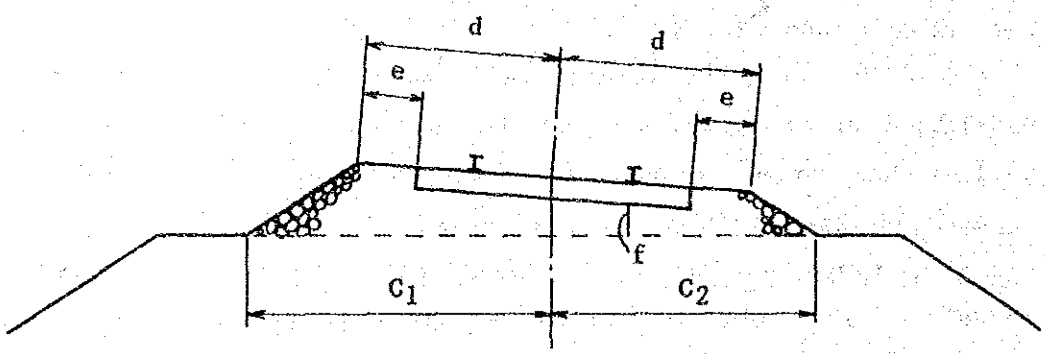
Item / Type	a	b	c	d	e	f
PC sleeper	2,440	570	1,870	1,315	400	200



(b) Curve section

(Unit: mm)

Type \ Item	C_1	C_2	d	e	f	Note
PC sleeper	1,870 + 2.7C	1,870 - 1.2C	1,315	400	200	C: Cant (mm)



Source: Study Team

(3) Main features of curve

The following will be applied to improve curves.

1) Vertical curve

Vertical curves with the following curve radius are to be inserted at the change points of gradients in the main track.

- Curve section of plane curve radius of less than 700 m: R = 4,000 m
- Other curves and straights: R = 3,000 m

2) Transition curve

(a) Shape of transition curve

The plane shape of transition curve generally resorts to the cubic parabola or sine curve. The cubic parabola shows the straight change of curvature and diminishing of cant, which is called the straight diminishing. On the other hand, the sine curve shows the curving change of curvature and diminishing of cant, which is called the curve diminishing.

The curve diminishing is applied to the section of high speed operation of 200 km/h for smooth train running. It, however, does not suit sections of low speed operation, due to the high accuracy required for its maintenance.

For the improvement of transition curve, therefore, the straight diminishing is applied.

(b) Length of transition curve

The length of transition curve differs depending on the track class as shown in Table 5.2.3.

Table 5.2.3 Calculation Formula for Length of Transition Curve

Length of transition curve \ Track class	1	2	3
L_1	0.8 C	0.6 C	0.4 C
L_2	0.01 CV	0.008 CV	0.007 CV
L_3	0.009 CdV	0.009 CdV	0.009 CdV

Remarks: The track is classified by the following line:

1: Rangoon - Mandalay line

2: Other main lines

3: Branch lines

L_1, L_2, L_3: Length of transition curve (m)

C : Set cant (mm)

Cd : Deficiency of cant (mm)

V : Maximum speed of train (km/h)

Source: Study Team

The longest one among L_1, L_2 and L_3 is to be raised to the multiple of 5 metres and regarded as the length of transition curve.

3) Cant

In order to increase the train speed, improvement of cant is generally required.

The permissible train speed when passing a curve is determined by the curve radius. Table 5.2.4 shows the permissible train speed calculated by the general formula ($V = 3.3\sqrt{R}$).

Table 5.2.4 Permissible Train Speed

Curve radius (m)	Degree of curve (°)	Permissible speed mile/h	km/h
699	2°30'	54	87
582	3°00'	50	80
499	3°30'	46	74
437	4°00'	43	69
349	5°00'	38	62
318	5°30'	37	59
291	6°00'	35	56

Source: Study Team

Generally the speed of trains passing a curve is not the same, so the cant is calculated using the average train speed.

(a) Average speed of train

The speed of trains passing a curve differs according to the express, ordinary passenger train and freight train. The average train speed is calculated by the formula below:

$$Vo = \sqrt{\frac{\sum NiVi^2}{\sum Ni}}$$

Vo = Average train speed (km/h)

Ni = Number of scheduled trains

Vi = Speed per type of train (km/h)

(b) Set cant

The set cant is calculated in the formula below using the average train speed.

$$Co = \frac{GVo^2}{127R}$$

If G = 1,000 mm, $Co = 7.87 \frac{Vo^2}{R}$

Co = Set cant (mm)

Vo = Average train speed (km/h)

R = Curve radius (m)

If the maximum train speed (V) is used in the formula instead of the average train speed (Vo), the equilibrium cant for maximum speed is obtained.

(c) Permissible deficiency of cant

The deficiency of cant is calculated in the formula below using the equilibrium cant for the maximum speed and set cant.

$$Cd = C - Co$$

Cd = Deficiency of cant (mm),

C = Equilibrium cant (mm)

Co = Set cant (mm)

If the side wind, effect of spring of rolling stock, riding comfort and safety ratio are taken into account, the maximum deficiency of cant is considered to be 50 mm. Therefore, the permissible deficiency of cant is to be 50 mm.

The cant should diminish gradually in the whole transition curve.

4) Slacking

The slacking as shown in Table 5.2.5 is arranged in curve sections with a curve radius of less than 437 metres (4°00').

Table 5.2.5 Slacking

Curve radius (m)	Degree of curve (°)	Slacking (mm)
291	6°00'	10
318	5°30'	8
349	5°00'	6
437	4°00'	4
499	3°30'	0

Source: Study Team

The slacking should diminish gradually in the whole transition curve.

5-3 Telecommunication

5-3-1 Improvement Plan

(1) Present condition

The present condition of BRC's telecommunication facilities is that circuits are composed mainly of the four bare wires borrowed from PTC, and that these wires are often in bad condition, leading to poor and unreliable telecommunication. To supplement this inadequate condition, the medium and high frequency wireless system is in use, but no means of telecommunication is available between those points where such equipment is lacking. And, what is worse, the wireless equipment is overaged and in poor condition as a whole, communication being often interferred by other radio waves.

BRC's services are carried out centered on train control communication service. With the services being expanded, it is not efficient and effective to transmit a variety of information among many places only via control telephones. It is considered necessary to improve the existing facilities and provide additional modern equipment.

(2) Outline of improvement

Under these circumstances, an improvement plan will be prepared with alternative Plans A and B, as shown in Table 5.3.1.

- to provide a UHF microwave system and underground cables, with natural disasters and social conditions taken into account, since the transmission lines are essential for telecommunication.
- to provide a telephone exchange at each main station and workshop. Electronic switching system will be adopted for large capacity, and crossbar system for small capacity.
- to provide the control telephone system, using the same circuit configuration as it is, and the frequency selective calling system between the main equipment and slave telephones.
- to provide a train radio system, 400 MHz band. Base station will be established at each railway station in such a way as to enable them to communicate almost over the entire line, mainly between controller and driver. Stationmaster will be able to communicate with driver in the area covered by his base station. Extension communication to the Head Office will be possible by controller's handling of key. (not included in Plan B)
- to provide a wagon data processor unit at the central control office and each divisional control office. Instructions and wagon data will be transmitted via the general subscriber telephone line. (not included in Plan B)
- to provide a facsimile equipment at main stations for communication of freight information.
- to provide a passenger information equipment at platforms of main stations.

5-3-2 Function and Performance Specification

(1) UHF microwave system

Frequency will be 1.5 GHz, radio equipment with a capacity of 120 CH, frequency division multiplex, and leakage method.

Relay distance will be 30 km as a standard, and this distance will be shortened in and around large cities. Radio wave path will be set up with the 20 metre height of tree taken into account, and the strength of steel tower will be withstandable against a wind velocity of 46 metres per second.

Table 5.3.1 Installation in Improvement Plan

Plan A	Plan B
o UHF microwave network	
o Underground cable	Same as Plan A
(Terminal boxes are installed at long bridges and main level crossings)	(Terminal boxes are installed at 1 km interval)
o Telephone exchanges	Same as Plan A
o Control telephones	
o Facsimile equipment	
o Passenger information equipment	
o Train radio system	
o Wagon data processor system	-

Source: Study Team

Dust-free, air-conditioned radio equipment room will be provided. As for electric source, the battery with a capacity to feed the 3-hour load will be provided with the power outage taken into consideration. Reserve generator will be provided against power stoppage for long hours, and, if possible, commonly used for signalling equipment.

The transmitter or receiver in use, when out of order, will be shifted to a reserve automatically.

The above shift and other troubles of each radio station will be indicated on the supervision board at Rangoon, Toungoo, and Mandalay.

Table 5.3.2 shows the specification of UHF microwave system.

Table 5.3.3 shows the quantity of UHF microwave equipment.

Table 5.3.2 Specification of UHF Microwave System

Item	Contents	
Class of emission	1.5 GHz	
Frequency band	0.3 ~ 3.4 KHz	
Capacity	Radio 120 CH	
Noise level	CCITT Rec. G222	
System	Radio, stand-by set	
Voice frequency response	CCITT G232	
Alarm display Transmission power level low Receiver out-of-order Power source fuse out		
Wind velocity	46 m/sec	
Environment	Temperature Humidity	5°C - 40°C 15 percent - 65 percent

Source: Study Team

Table 5.3.3 Quantity of UHF Microwave Equipment

Item	Contents	Quantity
Radio set	1.5 GHz	44
Terminal equipment	60 CH	28
Supervision equipment		3
Steel tower	40 - 70 m	23
Antena	3 - 4 m	44
Power source		23

Source: Study Team

(2) Underground cable

A hundred pairs of aluminum shielded tape armoured cables will be provided between Rangoon and Mahlwagon, and 30 pairs between Mahlwagon and Pegu, for ac electrification. On the other hand, 20 pairs of polyethylene shielded tape armoured cables between Pegu and Myohaung will also be provided, and 50 pairs between Myohaung and Mandalay. The cables between Rangoon and Pegu will include 4 sets of quad cables, between Pegu and Myohaung 2 sets, and between Myohaung and Mandalay 5 sets.

The cables will be buried in the roadbed with steel pipes used at the part crossing the bridge for protection purposes. Five pairs of branch cables will be provided at the point connecting cables every 1 km. Terminal boxes will be provided at a long bridge and level crossing in order to branch and connect the circuit to the control office with the telephone circuit between stations. A telephone line will be provided between main level crossing and its closer station and used for transmitting the information of train approaches.

In the case of no train radio system planned, terminal boxes will be installed between stations at intervals of 1 km. At each station, distribution room will be set up with terminal board provided to connect with cable cores.

Fig. 5.3.1 shows the configuration of circuits as a whole.

Table 5.3.4 shows the specification of cable.

Table 5.3.5 shows the composition of cable.

Table 5.3.6 shows the quantity of cable facilities.

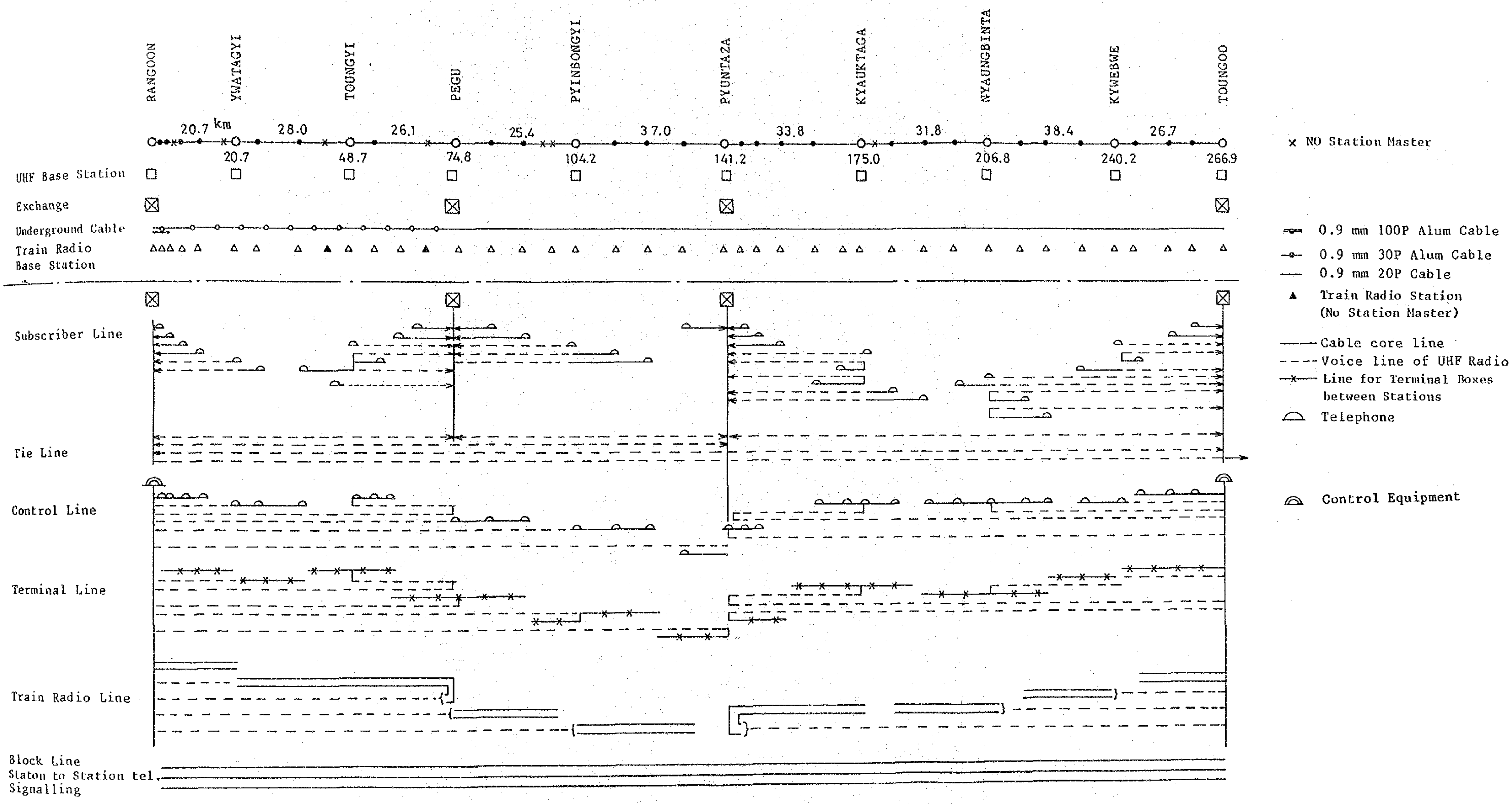


Fig. 5.3.1 Composition of Transmission Line (1)

Source: Study Team

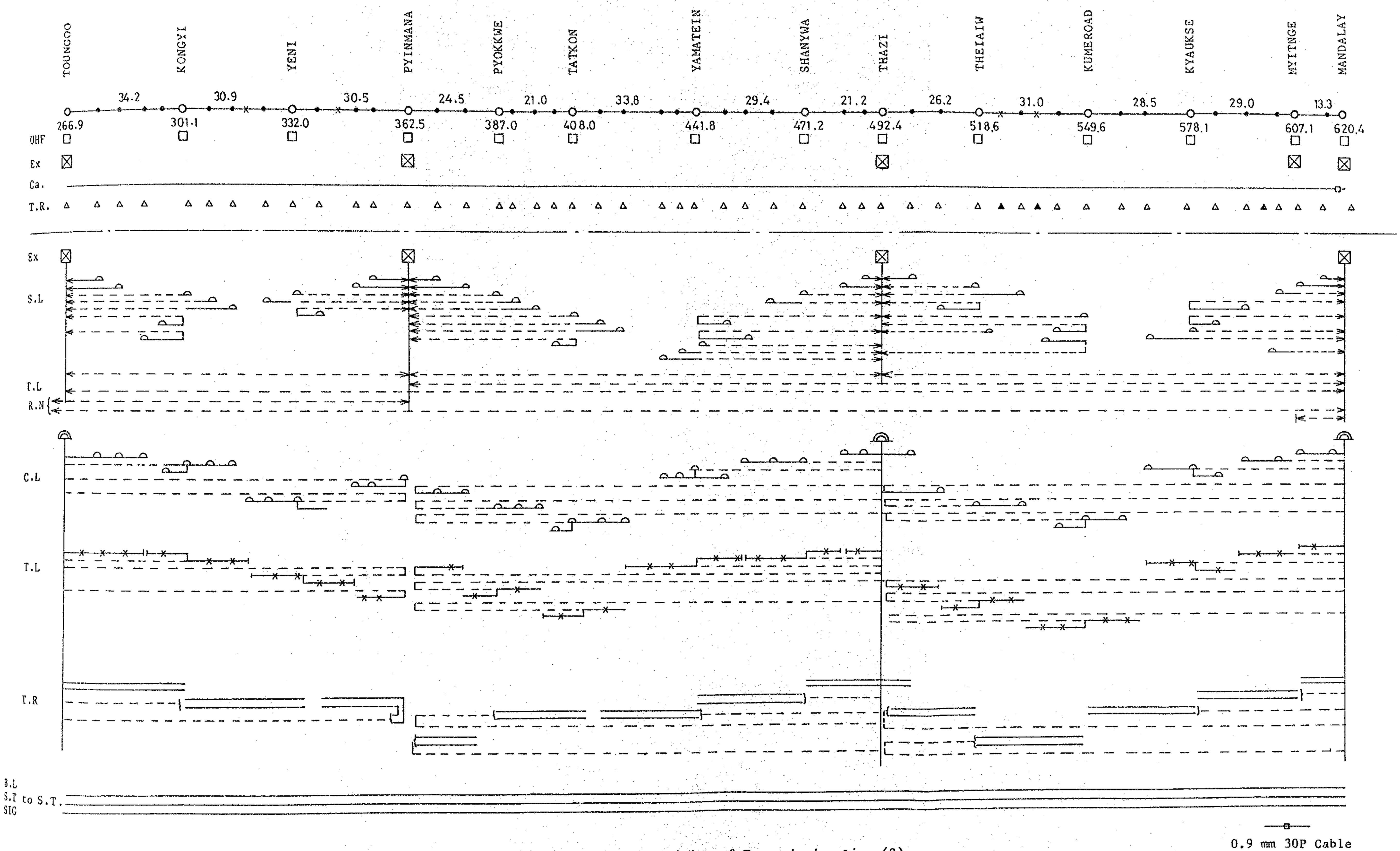


Fig. 5.3.1 Composition of Transmission Line (2)

Source: Study Team

Table 5.3.4 Specification of Cable

Item		Contents
Insulated conductor		Copper
Insulater		Cellular polyethylene
Conductor diameter		0.9 mm
Type	Aluminum cable	Steel tape armoured corrosion proof. Screening factor: less than 0.4
	Polyethylene cable	Steel tape armoured corrosion proof, jelly filled.

Source: Study Team

Table 5.3.5 Composition of Cable

Section	Pairs	Composition	Type
Rangoon - Mahlwagon	100 P	Common 92 star quad 4	Aluminum shield armoured
Mahlwagon - Pegu	30 P	Common 22 star quad 4	Aluminum shield armoured
Pegu - Myohoung	20 P	Common 16 star quad 2	Polyethylen shield armoured
Myohoung - Mandalay	30 P	Common 20 star quad 5	Polyethylen shield armoured

Source: Study Team

Table 5.3.6 Quantity of Cable Facilities

Item	Contents	Quantity
Underground cable	100P 0.9 Alum	4000 m
Underground cable	30P 0.9 Alum	72500 m
Underground cable	30P 0.9	4500 m
Underground cable	20P 0.9	552000 m
Cable joint		1300
Terminal board	Each station	89
Terminal box	Long bridge side	157
Magneto telephone	Main level crossing	40

(3) Telephone exchange

Telephone exchange will be provided at Toungoo and Mandalay as a time division exchange system, and at Pegu, Pyuntaza, Pyinmana, Thazi and Myitnge as a crossbar system.

Mandalay exchange will be equipped with cordless switchboard to connect with PTC tie line for receiving calls from PTC exchange. Calls from BRC telephones to PTC exchange will be dialed, except a certain number of telephones. Information on telephone numbers will be available at Mandalay exchange; attendant console will be provided to receive calls from other exchanges as well as from its own exchange.

Serious troubles of time division exchange will be transmitted to maintainers, and not so serious ones monitored through the self-diagnosing program or printed out. Circuit troubles will be recorded by computer.

The serious troubles of crossbar exchange will be indicated by a lamp provided at the place where maintainers are stationed, and light troubles recorded by trouble recorder.

Battery will be able to feed the current for 3-busy hours, with reserve generator provided.

Intercommunication system in major stations and yards will be installed at each station with exchange provided except Myitnge and in the yard of Mahlwagon and Myohaung.

Table 5.3.7 shows the capacity of each exchange and the numbers of existing telephone terminals.

Table 5.3.7 Composition of Exchange

Place	Capacity	Number of terminals
Pegu	50	30
Pyuntaza	30	20
Toungoo	100	80
Pyinmana	100	40
Thazi	100	50
Myitnge	200	100
Mandalay	200	120

Source: Study Team

Table 5.3.8 shows the specification of time division exchange.

Table 5.3.9 shows the specification of crossbar exchange.

Table 5.3.10 shows the quantity exchange equipment.

Fig. 5.3.2 shows the system block diagram of time division exchange.

Fig. 5.3.3 shows the composition of two step crossbar exchange.

Location of UHF and exchange equipment is shown in Appendix 5.3.

Table 5.3.8 Specification of Time Division Exchange

Item	Contents
Traffic condition	More than 3.6 HCS/station
Redundancy	Main parts duplicate
Number of routes	Appointment
Number of trunks per route	Appointment
Number of ATT consoles	Appointment
Calling method	Dial pulse 10 pps Double tone multi-frequency Automatic recall
Cross talk attenuation	More than 65 dB at 1 kHz
Idle circuit noise	Less than -65 dBm
Insertion loss Station to trunk Trunk to trunk	 0 dB 0 dB
Loop resistance	1200 ohms
Line impedance	600 ohms
Leakage resistance	More than 20,000 ohms
Signal voltage and frequency	More than 70 V 20 Hz
Alarm	Fuse out
Trouble	Recording in operating console
Environment	Temperature 5°C - 30°C Humidity 15 percent - 65 percent

Source: Study Team

Table 5.3.9 Specification of Crossbar Exchange

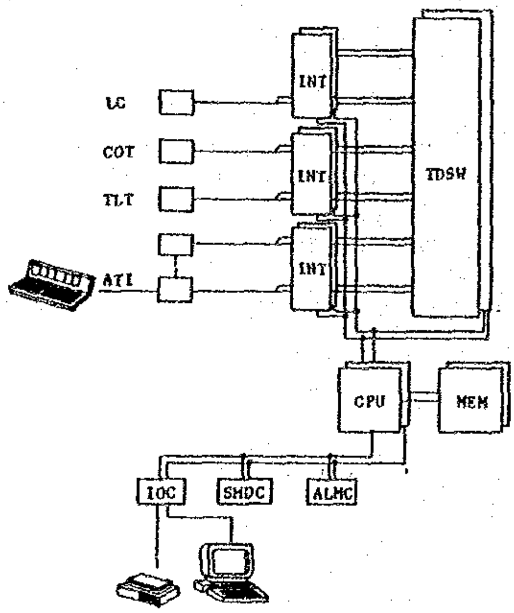
Item	Contents
Traffic condition	More than 3.6 HCS/station
Number of routes	Appointment
Connection stage	Capacity more than 200 2 wire 2 step Capacity less than 199 2 wire 1 step
Calling method	Dial pulse 10 pps Multi-frequency code signalling
Cross talk attenuation	Less than 65 dB at 1 kHz
Insertion loss	Less than 1 dB
Loop resistance	1200 ohms
Line impedance	600 ohms
Leakage resistance	More than 20,000 ohms
Alarm	Fuse out
Trouble	Recording on trouble recorder
Environment	Temperature 5°C - 50°C Humidity 15 percent - 80 percent

Source: Study Team

Table 5.3.10 Quantity of Exchange Equipment

Item	Contents	Quantity
Time division switch board	200 Line	1
Time division switch board	100 Line	1
Cross-bar exchange	200 Line	1
Cross-bar exchange	100 Line	2
Cross-bar exchange	50 Line	1
Cross-bar exchange	30 Line	1
Terminal board		7
Telephone		500
Intercommunication set	Main station	9
Power source		7

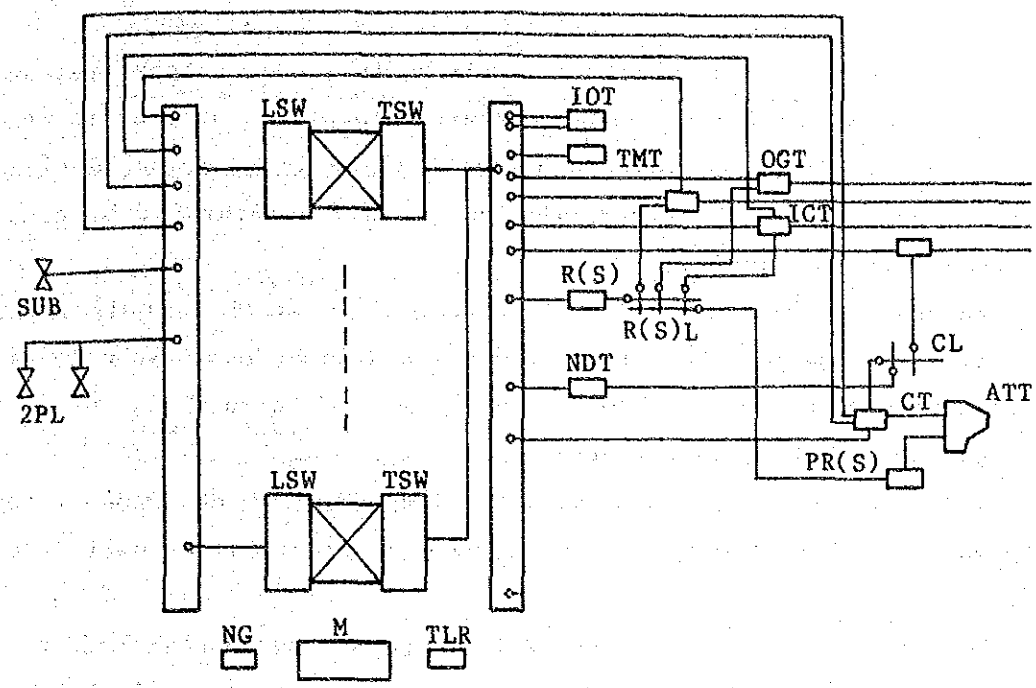
Source: Study Team



ABBREVIATION	DESCRIPTION
LC	Line Circuit
COT	Central Office Trunk
TLT	Tie Line Trunk
ATI	Attendant Console Interface
INT	Interface between TDSW and Port Card
TDSW	Time Division Switch
CPU	Central Processing Unit
MEM	Memory Circuit
IOC	I/O Controller
SMDC	Station Message Detail Recording System Controller
ALMC	Alarm Controller

Fig. 5.3.2 System Block Diagram of Time Division Exchange

Source: Study Team



ATT	Toll board by semiautomatic connection
BWT	Both way trunk
CL	Cord link
CT	Cord trunk
IOT	Inter-office trunk
ICT	Incoming trunk
LSW	Line switch
M	Marker
NG	Number group
OGT	Outgoing trunk
SUB	Subscriber
TMT	Two party manual trunk
TLR	Translator
TSW	Trunk switch
2PL	Two party line

Fig. 5.3.3 <u>Composition of Two Step Crossbar Exchange</u>

Source: Study Team

(4) Control telephone

The location of control offices will be the same as they are, and the configuration of control telephone circuits almost the same as it is. The number of circuits to be newly provided will be large compared with only one existing circuit; therefore, the number of telephones to be connected per circuit will be small.

Frequency selective calling system will be used to call stations. Respective stations can be called, and all stations simultaneously called. Calling from stations to control offices will also be made by this frequency selective calling system.

Call loss of these line must be less than 20 dB between control telephone and slave telephones and in case of simultaneous call less than 40 dB.

Battery will supply the control telephone equipment with electric power source. The battery at each station, if available, will be used for slave telephones, and if not available, dry cell.

Table 5.3.11 shows the specification of control telephone equipment.

Table 5.3.12 shows the quantity of control telephone equipment.

Table 5.3.11 Specification of Control Telephone Equipment

Item	Contents
Number of lines	More than 20
Number of slave telephones in one line	More than 10
Calling method	One voice frequency
To slave telephone	
(Individual and simultaneous call)	
From slave telephone	One voice frequency
Impedance	600 ohms

Source: Study Team

Table 5.3.12 Quantity of Control Telephone Equipment

Item	Contents	Quantity
Control Equipment	20 Line	4
Slave Telephone		120
Carrier Board		2
Power Source		5

Source: Study Team

(5) Train radio system

Train radio will be provided to facilitate the communication between driver and controller during the operation of the train. A circuit will connect engine drivers and a control office. The circuit can be extended to the Head Office through handling of key by a controller.

A base station will be established at each station. Within the area covered by the base station, the stationmaster will be able to communicate with the driver of a train by radio system.

The frequency for train radio system will use 400 MHz band, the selection of the band being made by the restricted height of the antenna attached to the locomotive. In addition to each station, some unmanned base stations will be installed on the long-distance section between stations. The same frequency will be used over the entire line; therefore, call at the boundary of control jurisdiction will be negotiated between the controllers on both sides.

A locomotive antenna will be provided on the roof, radio equipment in engine room, and a handset at the places easily handled.

Press-to-talk system will be adopted for calling. The circuit between base station and control centre will be configurated by UHF and cable, and that between control offices and Head Office by exclusive UHF line.

The combination test of base station radio equipment, transmitter and receiver, will remotely be controlled from control centre to supervise the condition. The test of on-board radio equipment will be conducted, when the locomotive leaves or arrives at the engine shed with a test device installed at the shed.

Table 5.3.13 shows the specification of train radio system.
Table 5.3.14 shows the quantity of train radio equipment.
Fig. 5.3.4 shows the composition of train radio system.

Table 5.3.13 Specification of Train Radio System

Item	Contents	
Class of emission	400 MHz band	
Frequency band	0.3 - 3 KHz	
Number of channel	one	
Signal-to-noise ratio	More than 30 dB	
Output	5 W	
Line impedance	600 ohms	
Environment	Temperature	5°C - 50°C
	Humidity	15 percent - 90 percent
Wind velocity	46 m/sec	

Source: Study Team

Table 5.3.14 Quantity of Train Radio Equipment

Item	Contents	Quantity
Radio set	400MHZ 5W Base station	89
Radio set	400MHZ 5W Locomotive	51
Steel tower	25 m	66
Antenna	Base station	176
Antenna	Locomotive	51
Control set	Base station	89
Control equipment	Control office	4
Control console		4
Telephone		95
Power source	Base station	89
Power source	Locomotive	51

Source: Study Team

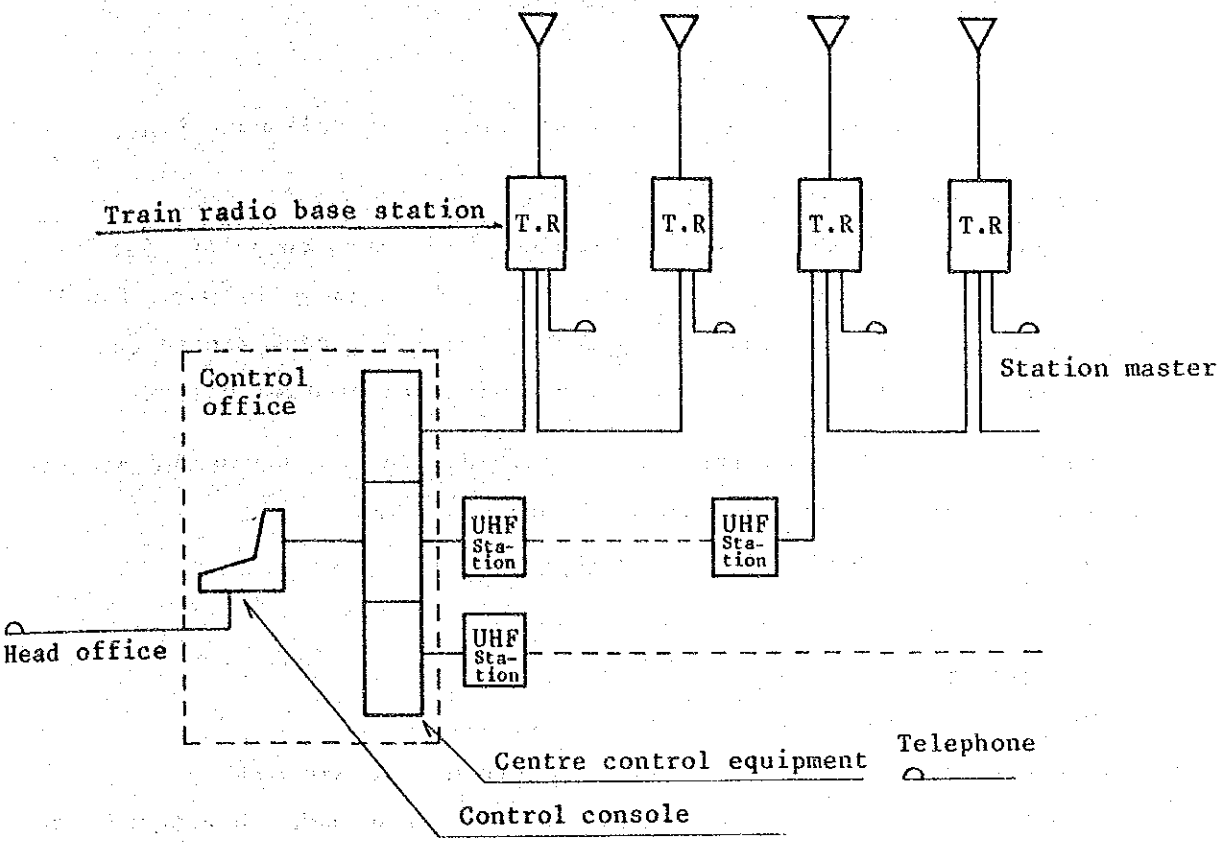


Fig. 5.3.4 Composition of Train Radio

Source: Study Team

(6) Wagon data processor system

Wagon data processor unit is installed at the central control office and each divisional control office. Composition of the unit is shown in Fig. 5.3.5.

Configuration of the system is shown in Fig. 5.3.6 and data will be transferred via the telephone line.

The basic function of the system is as follows:

- Computer for divisional control

Wagon data such as the type and condition of wagons entered through the keyboard is classified and computed according to the type, condition and destination of the wagon. Based on the wagon data, the wagon distribution schedule is made and printed out.

- Telecommunication control unit

  Data is transferred via the general subscriber telephone line.

- Computer for central control

  Based on the wagon data received from the computer for each divisional control office, the distribution schedule is made for the wagons operated between divisional control offices, and printed out, and the data is transferred to the related divisional control office.

Following are the environmental conditions of the equipment used in this system, and the specifications of each equipment.

Environmental conditions for operation

Temperature for operation	5 - 35°C
Temperature for storage	0 - 45°C
Temperature change	10°C/hr or less
Humidity	40 - 80 percent (no dewing)
Vibration	0.2G or less (in both horizontal and vertical directions)

Quantity of the equipment

Equipment	Quantity
Central control processor (capacity of memory 512KB)	6 sets
Display unit (color display unit, keyboard)	6 sets
Serial printer unit	6 sets
Flexible disc unit (capacity of memory 1MB x 2)	6 sets
Fixed disc unit (capacity of memory 22MB x 2)	6 sets
Telecommunication control unit	6 sets

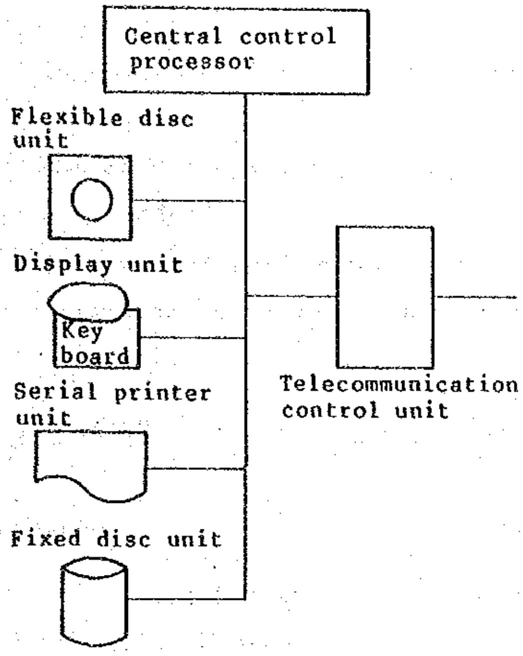


Fig. 5.3.5 Composition of Wagon Data Processor Unit

Source: Study Team

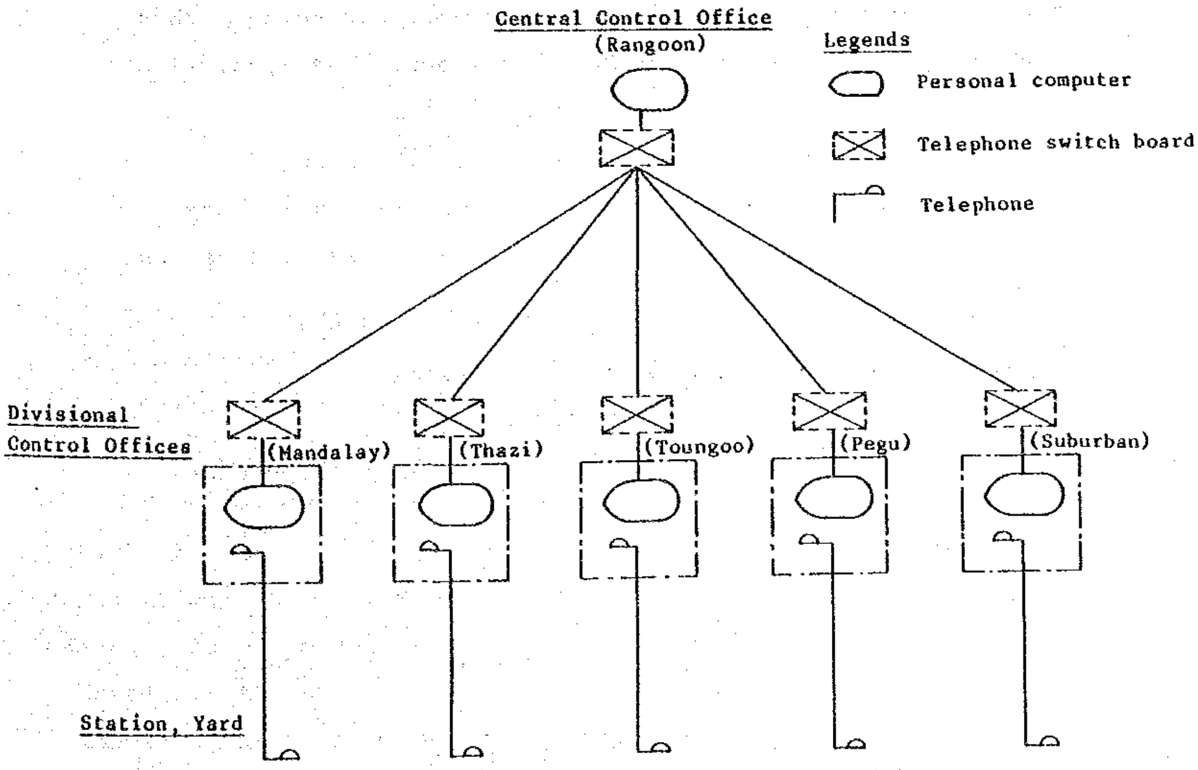


Fig. 5.3.6 System Configuration of Wagon Data Processor System

Source: Study Team

(7) Facsimile equipment

Facsimile system will be provided for transmitting freight information between control offices and main stations and also between main stations, especially the information to marshalling yards about the order of wagons of freight trains for higher yard operation efficiency.

Table 5.3.15 shows the specification of facsimile equipment.

Table 5.3.16 shows the quantity of facsimiles equipment.

Table 5.3.15 Specification of Facsimile Equipment

Items	Contents
Communication system	Half-duplex
Scanning method	Solid scannig
Size of manuscript	Max. 254 mm
Effective receive width	207 mm
Density of scannig line	Horizontal 8 dot/mm Vertical 3.85 dot/mm
Sending process	Frequency band suppressing method
Modulation system	- Quadrature amplitude modulation - Phase modulation - Frequency shift keying - Amplitude modulation - phase modulation - Vestigial side band
Communication speed	9600/7200/4800/2400 bps
Recording method	Thermal recording
Environment	Temperature 5°C - 36°C Humidity 45 - 85 percent

Source: Study Team

Table 5.3.16 Quantity of Facsimile Equipment

Item	Quantity
Facsimile set	8

Source: Study Team

(8) Passenger information equipment

Passenger information equipment will be provided in the platforms of major stations to indicate train number, arrival and departure time, etc.

Table 5.3.17 shows the specification of passenger information equipment.

Table 5.3.18 shows the quantity of passenger information equipment.

Table 5.3.17 Specification of Passenger Information Equipment

Item	Contents
Indication form	Sheet rolling type
Control method	Direct current by push button

Source: Study Team

Table 5.3.18 Quantity of Passenger Information Equipment

Item	Quantity
Indicator	48
Controller	15

Source: Study Team

(9) Comparative study of Plans A and B

Plan A will introduce the train radio system and wagon data processor systems, which are not included in Plan B.

The train radio system is a very useful means for effective train control, enabling direct communication between the controller and driver. Especially in cases of operational troubles, such as engine breakdowns or signalling failures, train delay time will be reduced considerably due to quick and smooth communication by train radio system.

However, the use of the train radio system in operational troubles will decrease in frequency on the whole, along with other installations improved under this or other related projects. The provision of wayside telephone boxes will substitute for the function of the train radio system. The investment cost needed for the train radio system will be too high to justify the effects as mentioned above.

The wagon data processor system, in general, will contribute to effective wagon operation, resulting in a considerable reduction of wagons needed.

However, judging from a relatively small amount of wagons to be handled, the wagon control of the Mandalay line will be properly handled without a computer system. The wagon data processor system does not sound so promissing in consideration of the operational conditions of freight trains at present and in the near future.

Consequently, the adoption of Plan B, which is characterized by lower costs, as the execution plan is recommended.

5-4 Signalling

5-4-1 Improvement Plan

(1) Present condition

Study on the signalling facilities at all stations revealed that various facilities at each station have been used for 30 to 50 years since installation, and spare parts are not easily obtained. The paper line-clear ticket system is applied for train operation at almost all sections of the Mandalay line. The line-clear ticket delivery by a driver, insufficient visibility of signals, and interlocking malfunction of facing points greatly restrict train running speed at station yards.

The Mandalay line crosses main roads at 21 points, one of which is grade separated. A gate keeper who watches the approaching train by eye and ear manually closes the gate. The closing time of the gate differs at each level crossing. If gates are not closed even when a train approaches, the train sounding a horn reduces speed or stops before the level crossing, and waits for the closing of the gate. Almost all level crossings lack power source or facilities to communicate with stations.

(2) Outline of plan

On the Mandalay line, the following improvement will bring about more effective, safe train operation as well as shortened train scheduled time.

- Efficient train operation handling
- Signals with high visibility
- Locking at facing points
- Quick operation of gates at level crossings

In view of such a situation, we first proposed a change to color light signals, relay interlocking, and electric locking devices at each station, adoption of a token system on single-track sections and a tokenless system on double-track sections and level crossing improvement.

However, due to the social situation, poor power supply availability and frequent train accidents by violation of signal, it was proposed not to install ground facilities as much as possible. Based on this, an electronic token system with an ATS function and cab signal were proposed as Plan A, however, problems of the cab signal with driver's handling were underlined. At the control office, it was proposed to install a train operation display unit using the electronic token system.

In alternative Plan B, two drafts were proposed. In Draft-1, each station is equipped with a transmitter in order to add a train operation display unit to the originally proposed system. In addition to the blocking line, a line for the operation display unit is newly laid.

In Draft-2, an electronic token system is adopted for both the single- and double-track sections. The system operates and approves blocking and control of signals through one control table operated by the stationmaster. The transmission to the train operation display unit can be made via the blocking system circuit between stations. The CRT is used as the operation display unit.

Considering the poor power source condition of the Mandalay line, the power supply improvement plan for signalling and telecommunication facilities is proposed as seen in Chapter 5-5.

As to level crossings, an approach indicator and flashing red lights with intermittent alarm to inform the gate keepers of the timing of gate closing and caution the people, will be installed. However, the gate keeper will close the gate manually as he does now, since safety cannot be assured by automatic gate operation.

Table 5.4.1 shows alternative Plans A and B for each station and main roads.

Table 5.4.1 Alternative Plan A and B for each Station and Main Roads

Unit		Alternative Plan A	Alternative Plan B		
			Draft-1		Draft-2
Interlocking device (at major stations)		Electronic interlocking device	Relay interlocking device		Same as left
Interlocking device (at small stations)		Electric locking device (Point lever will be provided by BRC)	Same as left		Same as left
Signal		Cab signal	Wayside signal		Wayside signal
Blocking equipment		Electronic block equipment	Double track section	Tokenless system	Electronic token system
			Single track section	Token system	
ATS function		With ATS function	Without ATS function		Same as left
Train detector		Wayside coil	Short track circuit or check-in/check-out		Tail check
Control facility		Train operation display unit (CRT)	Simple train operation display unit		Train operation display unit (CRT)
Power source facility	With EPC power source	Engine generator (stand-by)	Same as left		Same as left
	Without EPC power source	Power supply from adjacent station via. overhead electric power lines. Engine generator (Stand-by)	Same as left		Same as left
Level crossing facilities		New installation of approach alarm and flashing Lamp Manually operated gate No alarm light due to power supply condition Solar cell or power supply from neighboring station via overhead electric power lines.	Same as left		Same as left
Train separation		Automatic tail check	Double track line	Axle counter or automatic tail check	Tail check
			Single track line	Tail lamp check by stationmaster	

5-4-2 Function and Performance Specifications

(1) Alternative Plan A

1) Electronic interlocking device (at Pegu, Pyuntaza, Myohaung, Thingangyun)

The electronic interlocking device integrates the microcomputer, standardized hardware and the standard programme for the interlocking function, etc., applicable to any station. With different operational and interlocking conditions, the system is capable of control at any station.

The principle of the interlocking applied is the same as that of the conventional relay interlocking device, and the system is composed of hardware and software based on the fail-safe principle.

The electronic interlocking device is standardized. Differing from the relay interlocking device, the electronic interlocking devices for all stations can be designed, manufactured, inspected, installed and maintained based on common specifications, which reduces the cost. The standardized work for design, inspection and trouble-shooting can be automated, which shortens the time for work and prevents accidents due to human mistakes.

The following are the advantages.

(a) Consistent work in plant manufacturing

(b) Automatic interlocking inspection and standardized inspection method

(c) Elimination or reduction of labour for wiring at the construction site

(d) Shortened construction period

(e) Simplified maintenance work

(f) Simplified interlocking modification.

Table 5.4.2 shows the amount of equipment for Electronic interlocking device.

Table 5.4.2 Amount of Electronic Interlocking Device

Item		Quantity
Electronic interlocking device	Newly installed	4 stations
Electric switch machine	Newly installed	- do -
Wayside signal	Newly installed	- do -
Track circuit	Newly installed	- do -
Engine generator	Newly installed	- do -
Signal cable	Newly installed	- do -
Semaphore signal	Removed	- do -
Level crossing equipment	Improved	- do -

Source: Study Team

Table 5.4.3 shows the main functions and performance of electronic interlocking devices.

Table 5.4.3 Main Functions and Performance of Electronic Interlocking Devices

Item			Description
Function	Interlocking		Route selection, signal control, etc.
	Control display board		Display, input data, etc.
	Maintenance data management		Record of control, etc.
Performance	Power source voltage		200 V $\pm$ 40 V AC 50 Hz
	Environment characteristics	Temperature	0°C - 50°C
		Humidity	95 percent or less
	Connection to external equipment		With a safety device and photo coupler

Source: Study Team

For details of function, performance and system configuration, refer to the Appendix. 5.4.(1).

2) Electronic token block system

The electronic token block system integrates the microcomputer, standardized hardware and the standard programme for the blocking function. The interlocking function is applicable to any station. With different operational and interlocking conditions, the system is capable of control at any station.

The hardware and programme according to the blocking and interlocking principle, are based on the fail-safe principle applied in conventional systems. Such standardization brings about an effect similar to that of electronic interlocking device. The electronic token block system consists of the ground unit for blocking and interlocking functions, on-board unit to display the cab signal, and the operational display unit to display the operational condition of trains in the related sections. The wireless is used to transmit the information of signals between the ground and the on-board units.

Fig. 5.4.1 shows the relation between the signal display in cab signals.

Table 5.4.4 shows the amount of equipment for electronic token block system.

Table 5.4.5 shows the main functions and performance of electronic block equipment.

For details of function, performance and system configuration, refer to the Appendix 5.4.(2).

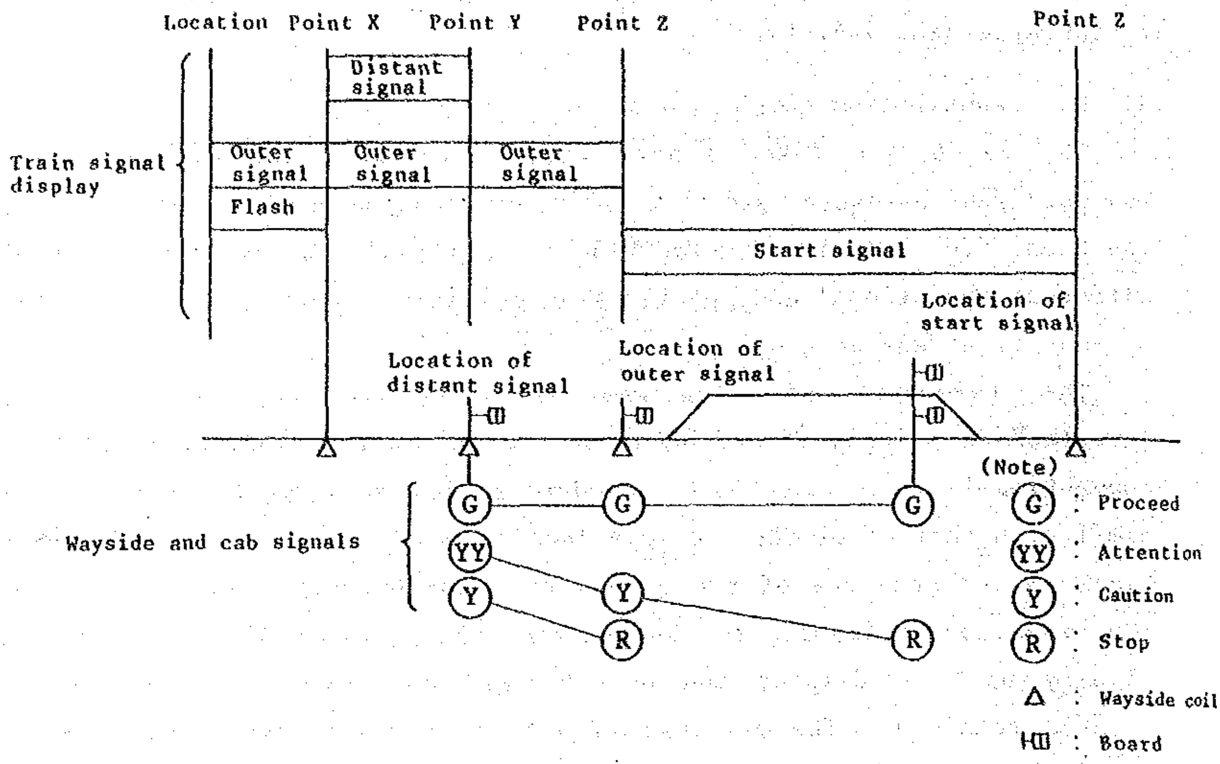


Fig. 5.4.1 Signal Display in Cab Signal

Source: Study Team

Table 5.4.4 Amount of Equipment for Electronic Token Block

Item		Quantity
Electronic block equipment	Newly installed	for all sections
Point	Improved	- do -
Cable	Newly installed	- do -
Engine generator	Newly installed	- do -
Semaphore signal	Removed	- do -
Wireless ground equipment	Newly installed	- do -

Source: Study Team

Table 5.4.5 Main Functions and Performance of Electronic Token Block Equipment

Item				Description
Function	Ground	Blocking unit		Setting of operational direction and release of locking.
		Interlocking		Route control
		Control display board		Display and setting of train number
		Train detection		Detection of train position by wayside coil
		Tail check		Train separation check
	On-board unit	Signaling indication		Ringing control from station unit
		ATS (Automatic Train Stop)		Function to stop train by signalling from ground
		Train position detecting		Train position detection by wayside coil
		Control display board		Train number setting
Performance	Ground and on-board unit	Wireless frequency		400 MHz band
		Transmitting power		1 W
		Transmission rate		1200 BPS
		Power source voltage	Ground	AC 200 V ± 40 V 50 Hz
			On-board	DC 72 V ± 14 V
		Environ-mental conditions	Temperature	0°C - 50°C
			Humidity	95 percent and less
		Vibration		1 - 5 Hz Total amplitude 10 mm
				5 - 30 Hz Accelerating maximum amplitude 1G
		Impact		3G (29.4 m/S^2) 4 repetitions
		Connection to outside units		With a safety device or photo coupler

Source: Study Team

3) Train operation display unit

The display unit collects the data of each station and displays the train position and direction. The CRT monitors the operational condition of trains. Table 5.4.6 shows the amount of equipment for the operation display system. Table 5.4.7 shows the main functions and performance.

Table 5.4.6 Amount of Train Operation Display

Equipment		Quantity
Train operation display	Newly installed	4 stations
Signal cable	Newly installed	- do -
Power source equipment	Newly installed	- do -

Source: Study Team

Table 5.4.7 Main Functions and Performance of Train Operation Display

Item			Description
Function	Display		Display of train number and position
	Train number monitor		Monitoring of train number
	Simultaneous stop		Function for emergency stop of all trains in station area
Performance	Power source voltage		110 V $\pm$ 10 V AC 50 Hz
	Environmental conditions	Temperature	0°C - 50°C
		Humidity	95 percent or less

Source: Study Team

For details of functions, performance and system configuration, refer to the Appendix 5.4.(2).

(2) Alternative Plan B

1) Common facilities for alternative plans Draft-1 and Draft-2.

(a) Relay interlocking device (at Pegu, Pyuntaza, Myohaung)

The relay interlocking device incorporating compact relays sets the route of a train and controls the electric point and signaling facilities. Each station has its own control board. Table 5.4.8 shows the amount of equipment for the relay interlocking devices. Table 5.4.9 shows the main functions and performance of relay interlocking devices.

Table 5.4.8 Amount of Relay Interlocking Devices

Equipment		Quantity
Relay interlocking device	Newly installed	3 stations
Electric switch machine	Newly installed	- do -
Wayside signal	Newly installed	- do -
Track circuit	Newly installed	- do -
Engine generator	Newly installed	- do -
Cable	Newly installed	- do -
Semaphore signal	Removed	- do -
Level crossing equipment	Improved	- do -

Source: Study Team

Table 5.4.9 Main Functions and Performance of Relay Interlocking Devices

Item			Description
Function	Interlocking		Selection of train route and control of signalling facilities
	Display control board		Display of track condition and signal condition, lever position
Performance	Power source voltage		200 V ± 40 V AC 50 Hz, DC 24 V ± 10 percent
	Environment conditions	Temperature	0°C - 50°C
		Humidity	95 percent or less
	Connection to outside equipment		With an arrester

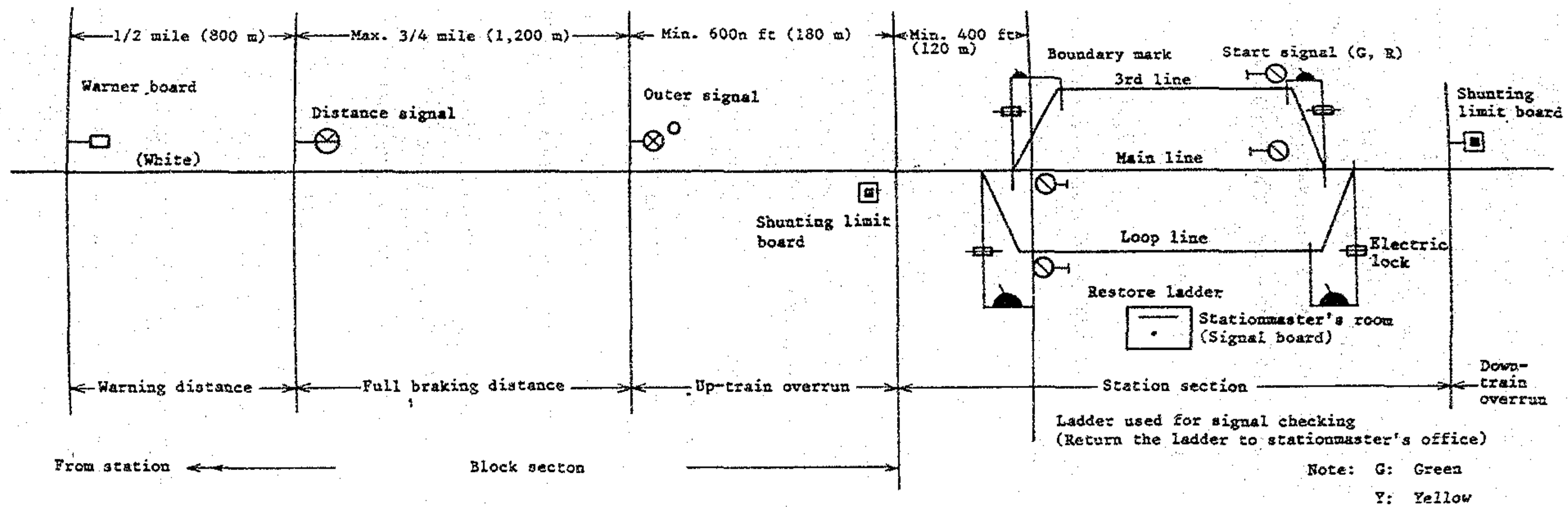
Source: Study Team

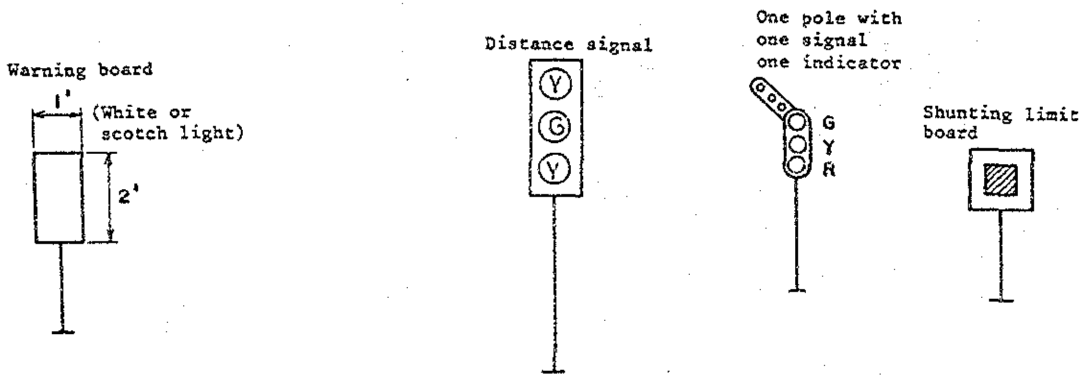
(b) Wayside signal

Outer signals and start signals are installed. Distant signals are also installed if required. Each signal should have visibility of approximately 1.5 kilometers. For a signal which requires less visibility, however, a transformer inside the signal is used for voltage adjustment. The lens of each signal should be covered to prevent breakage by stones.

Fig. 5.4.2 shows the layout of wayside signals.

Color Light Signal System for Signalling on the Main Line





Train		Signal indication			
Route	Opera-tion	Distance	Outer	Start	Indica-tion
Main line	Pass	G	G	G	X
	Stop	Y,Y	Y	R	X
Loop line	Pass	Y,Y	Y	G	O
	Stop	Y,Y	Y	R	O
Outer stop		Y	R		
Main, loop	Start			G	
Shunting		Y	R		

Fig. 5.4.2 Layout of Wayside Signal

2) Draft-1

(a) Block equipment

a) Double track section

Tokenless system is used. Block control is conducted based on train detection by short-track circuit or using a check-in/check-out system. Table 5.4.10 shows the main functions and performance of tokenless systems.

Fig. 5.4.3 shows the check-in/check-out system.

b) Single track section

Block control by a token system. The token system now used by BRC will be used after some modification.

(b) Train separation check

a) Double track section

Train separation is examined for by the axle counter, or by rear wheel detection using tail check method. Table 5.4.11 shows the main functions and performance of the axle counter.

b) Single track section

Tail-lamp checking by a stationmaster.

(c) Simple train operation display system

The operational conditions are manually recorded in the train operation display unit in accordance with reports by telephone from each station.

Or, the data at each station is transferred to the central office through each station unit. Table 5.4.12 shows the functions and performance of the data transmitter. Table 5.4.13 shows the number of main facilities in Draft-1.

Table 5.4.10 Main Functions and Performance of Tokenless System

Item			Description
Function	Blocking unit		Setting of operational direction and release of locking
	Control display board		Display of track circuit conditions and signal conditions as well as the input of block lever conditions
Perform-ance	Power source voltage		DC 24 V ±20%
	Environmental condition	Temperature	0°C - 50°C
		Humidity	95% or less
	Connection to outside unit		With a safety device

Table 5.4.11 Main Functions and Features of the Axle Counter

Item				Description
Function	Axle counting function			Proximity check of axle passing
	Axle number verification function			To verify axle number using the transmission line between stations
Perform-ance	Power source voltage			DC 24 V ±20%
	Frequency equipment			10 - 20 kHz
	Detected train speed			0 - 120 km/H
	Environ-mental condition	Wheel detector	Temperature	0° - 60°C
			Humidity	30 - 100%
		Equipment	Temperature	0° - 50°C
			Humidity	95% or less

Check-in/Check-out System

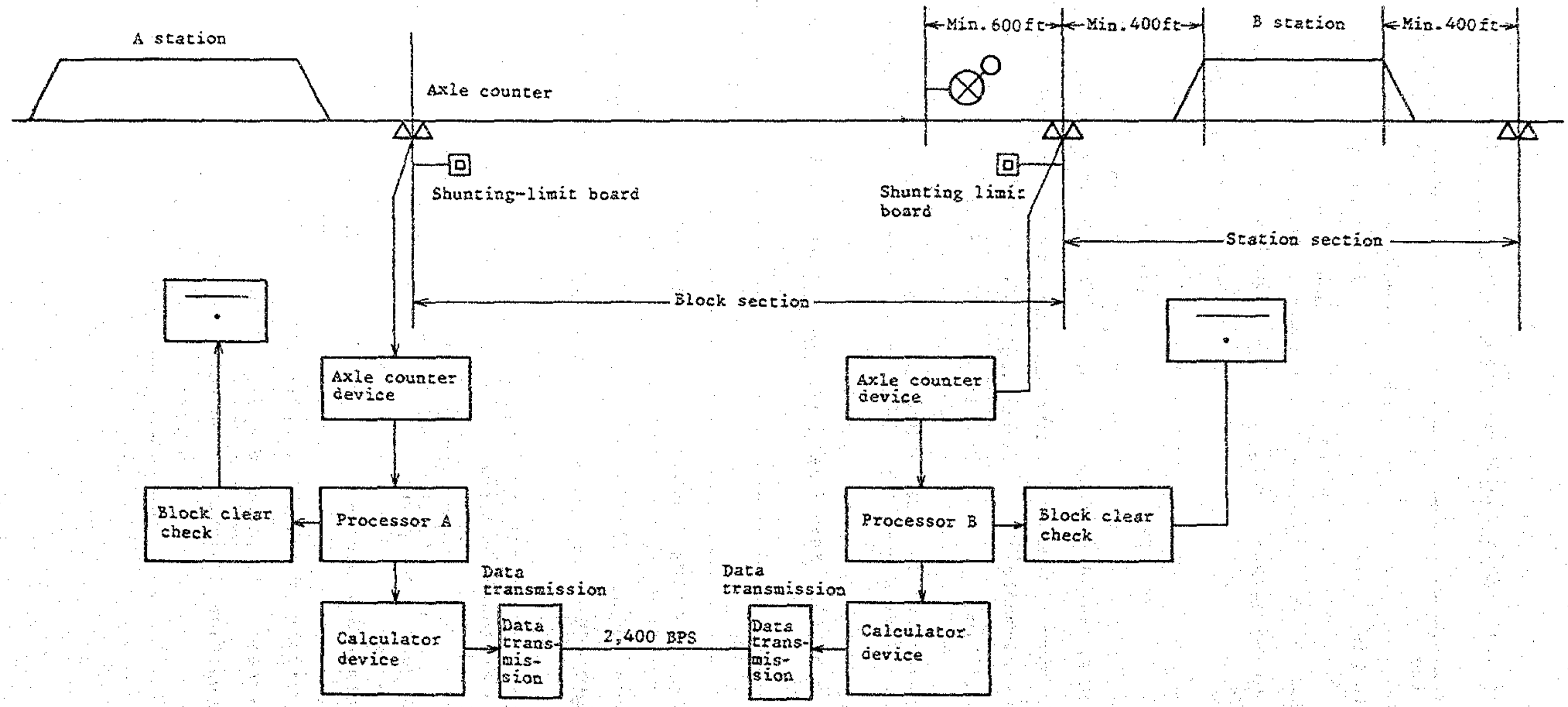


Fig. 5.4.3 Check-in/Check-out System

Table 5.4.12 Functions and Performance of the Data Transmitter

Item			Description
Function	Display function		Display operational conditions of trains at major stations
	Transmitting function		To receive data from major stations
Performance	Power source voltage		200 V ±40 V AC 50 Hz; DC 24 V +20% -10%
	Data transmission rate		1200 BPS
	Environmental condition	Temperature	0° - 50°C
		Humidity	30 - 90%

Table 5.4.13 Number of Tokenless Systems and Facilities in Draft-1

Equipment	Quantity	
Tokenless system	Newly equipped	for double sections
Token system	Improved	for single sections
Point	Improved	for all sections
Wayside signal	Newly equipped	- do -
Point locking device	Newly equipped	- do -
Short track circuit	Newly equipped	for double sections
Engine generator	Newly equipped	for all sections
Signal cable	Newly equipped	- do -
Mechanical signal	Removed	- do -
Level crossing equipment	Improved	20 sets
Axle counter or tail check	Newly equipped	for double sections
Simple operation display unit	Newly equipped	4 stations
Data transmitter equipment	Newly equipped	for all sections

3) Draft-2

(a) Block device

The block is controlled by the electronic token system, and train detection done by a tail check. The stationmaster operates the electronic token system, setting and approving the block. He also sets the signal control conditions. Table 5.4.14 shows the main functions and performance of the electronic token system.

(b) Train separation check

Train separation is examined by tail check devices.

Table 5.4.14 Main Functions and Performance of Electronic Token System

Item			Description
Function	Blocking		Setting and unlocking of operational direction and check of train existence in block sections train
	Logical		Checking of route condition and signal control Checking of train operation condition
	Input/output		Condition check of field equipment and signal display
	Transmission		Production and reception of data at each station
	Train detection		Train detection by tail check device.
Performance	Power source voltage		DC 24 V +20% -10%
	Environmental conditions	Temperature	0°C - 60°C
		Humidity	30 - 90 percent or more
	Data transmission rate		1200 - 2400 BPS
	Outside contact		With a safety device or photo coupler

(c) Train operation display unit

The condition of train operation for a maximum of 15 stations is displayed on the basis of train data obtained through the electronic token system at each station. Table 5.4.15 shows the main functions and performance of the train operation display unit.

Table 5.4.16 shows the number of main facilities in Draft-2.

For details of operation, refer to the Appendix 5.4.(3).

Table 5.4.15 Train Operation Display Unit

Item			Description
Function	Operation display function		Display of train number and location of train
	Train number control function		Control of train number
Performance	Power source voltage		110V ±10V AC 50 Hz
	Environmental conditions	Temperature	0°C - 50°C
		Humidity	95 percent and less

Table 5.4.16 Number of Electronic Token Systems and Facilities in Draft-2

Equipment		Quantity
Electronic token system	Newly installed	for all section
Point	Improved	- do -
Point locking device	Newly installed	- do -
Tail check	Newly installed	- do -
Engine generator	Newly installed	- do -
Signal cable	Newly installed	- do -
Mechanical signal	Removed	- do -
Level crossing equipment	Improved	20 sets
Operational condition display unit	Newly installed	4 stations

(3) Common facilities for alternative Plans A and B

1) Point

(a) Electric point machine

An electric point machine is equipped with the circuit controller, and its right and left locking rods are to be independent for splitting. The transformer is 100 V or 240 V. At Pegu station, the electric point machine is installed at the rail level, because it floods once or twice in a few years. The connecting rod with point machine should be raised, or waterproof machines should be used to prevent from flood trouble.

(b) Electric lock device (with electromagnetic switch lock device and circuit controller)

The control parts of electric lock devices are of waterproof type. The right and left locking rods moves independently.

(c) Point lever

The point lever is manually operated at site with a ratch handle to be locked with the electric lock device. It will be provided by BRC.

(d) Track circuit

The track circuit is provided for train detection. An inexpensive direct current track circuit immune to alternating current is used. The equipment should be concentrated, with installation near the track to be avoided as far as possible.

(e) Shunting signal

The shunting signal with three-routes, having protective lens should be used.

(f) Level crossing alarm

The alarm of train approach is given to the gate keepers by means of the track circuit, or the treadle, by which a gate keeper closes the gate. The operation time of the gate is two minutes and the approaching point is determined by the maximum speed of the train. No automatic barriers are installed.

Table 5.4.17 shows the amount of equipment for the level crossing.

Table 5.4.17 The Amount of Equipment for the Level Crossing

Equipment		Quantity
Approach alarm	Newly installed	20 sets
Train detector	Newly installed	40 sets
Power source device	Newly installed	20 sets

Source: Study Team

(4) Comparative study

1) Comparative study of Draft-1 and Draft-2 in Plan B

The following are the results of a comparative study of Plan-B.

In Draft-1, a train detection short-track circuit for a tokenless system, a signal control board, and a data transmitter for train operation display system are newly established. The cost of the tokenless system is considerably higher than that of an electronic token system (Draft-2).

The facilities in Draft-2 are common to each station, and the spare parts to be stored at these stations for the facilities can be used by all of them. With regard to Draft-1, the block and transmission lines for train operation control have to be separate while one line can be commonly used for Draft-2.

Draft-2 proposes facilities common to each station, which allows the consistent production of facilities at a factory, achieving lower cost as compared with these of Draft-1.

In connection with Plan B, we propose Draft-2 characterized by lower cost (about 10 percent) as the result of a cost comparison between Draft-1 and Draft-2.

2) Comparative study of Plans A and B

Table 5.4.18 shows the results of a comparative study of Plans A and B.

Table 5.4.18 Comparative Study of Plans A and B (Draft-2)

Item	Alternative Plan A	Alternative Plan B
Handling regulations for operation	New rules and regulations are necessary, resulting in two types (old and new)	Alternations not necessary.
Training for operational handling	Training necessary.	Training not necessary.
Signal failure	All stations are manually dealt with.	Other stations will not affected.
Commencement of operation	Commencement of operation on the completion of the whole line or a great part of the line.	Commencement of operation at every station.
ATS	ATS function is incorporated into the on-board system.	ATS function is not included.
Visibility of signal	Not hindered by weather conditions.	Sometimes hindered by weather conditions such as dense fog, etc.
Power consumption	Small because wayside signals are not used.	Comparatively large.
Vulnerability to theft or vandalism	Not vulnerable.	Vulnerable.

5-5 Power Source

5-5-1 Improvement Plan

(1) Present condition

Most stations are supplied with power by EPC (The Electric Power Corporation). However, about 30 percent of the stations on the Mandalay line, that is 26 stations, are not supplied with it. Many of the small stations near Mandalay station have no power supply. The engine generators installed at large stations are not fully utilized due to an insufficient oil supply and insufficient maintenance, and at some stations, they were found dismantled for repair.

(2) Improvement plan

In the long-term modernization programme, it was first planned that basically stations with EPC power would be supplied with a stand-by engine generator, and stations without EPC power supplied with engine generators both for main and stand-by use, considering the poor power condition on the Mandalay line. However, due to the oil supply and existing maintenance dificulties, the plan for engine generators was later replaced by alternative plans for solar cells and a power supply from nearby power substation. Table 5.5.1 shows a comparison of these two alternative plans.

In Plan B, the capacity of a solar cell and battery depends on the period of daily non-sunshine conditions and the loading capacity. In the case of several hundred watt loads, the power source in Plan B requires several times the expense of EPC power supply from nearby power substation. Therefore, Plan A is judged to be economically more advantageous for small stations without a power source and level crossings.

Table 5.5.1 Alternative Plan of Power Source

Condition of power supply	Scale of station yard	Plan A		Plan B	
With EPC power source	Large	Main power source:	EPC	Same as left	
		Stand-by power source:	Engine generator		
	Small	Same as above		Main power source:	EPC
				Stand-by source:	Solar cell
Without EPC power source	Small	Main power source:	To be supplied via newly laid power cable from nearby power substation	Main power source:	Solar cell
		Stand-by source:	Engine generator	Stand-by source:	Engine generator
	Level crossing	EPC power source from nearby power substation		Solar cell	

Source: Study Team

5-5-2 Function Specifications

(1) Engine generator

Air cooling system, automatic start-up, low noise unit type

At large station yard (4 - 10 kVA)

At small station yard (1 - 2 kVA)

(2) Power supply from nearby power substation

For the power supply from nearby power substation, an overhead electric power line is laid parallel to the railway track.

a. Power source (3 phase 11 kV)

b. 3 kVA load per station

c. 22 mm^2 bare or insulated line as an overhead electric power line

d. Utility poles made of used rails with pin insulators.

e. Pole span with 50 m

In comparing the costs for power supply of an overhead electric power line and that of a system using solar cells, the latter is about 3.8 times greater than the former.

5-6 Effect of Facility Improvement

The effects of investment for facility improvements are as follows.

(1) Increase in train speed

The improvement of tracks, signallings, and level crossings increases train speed and greatly reduces the scheduled time.

(The time reduction ratio of each plan for tracks, telecommunications and signallings is the same.)

(2) Improvement of punctuality

The track and signalling improvement will reduce the number of facility troubles, and ensure the punctuality of train operation. The strengthening of the control system and communication network speeds up information and data transfer and improves the efficiency of operational control work.

In Telecommunication Plan A, the introduction of train radio contributes to smooth communication in the case of engine trouble, and further improves the punctuality of train operation by reducing the time for train operational adjustments.

(The improvement ratio for the track and signalling plans are the same, but the improvement ratio of the Telecommunication Plans A and B differ.)

(3) Enhancement of safety

The track improvement will increase train operational safety and reduce the number of accidents. Signalling Plans A and B ensure the reliable operation of block devices and train separation checks.

In Signalling Plan A, especially, the introduction of ATS prevents accidents caused by driver error during operation.

(4) Increase of track capacity

The speeding up of trains and improved operational punctuality increases track capacity.

(5) Effective rolling stock operation

The installation of control telephones and train operation control display units as well as the increased train speed and improved punctual operation, increase the efficiency of rolling stock operation. In addition, the introduction of a wagon data processing system and facsimile equipment contribute to more effective wagon distribution.

(6) Reduction of fuel costs for train operation

The adoption of long-welded rails and PC sleepers contribute to smooth train runs and smaller train running resistance by eliminating the impact on rail joints and reducing track irregularity, which reduces the fuel consumption for operation.

(The reduction ratio differs in Track Plans A, B, and C.)

(7) Lesser amount of rolling stock damage

Smooth train runs attained by track improvement reduces axle and spring breaks and damage to other parts of the rolling stock, which reduces the repair costs for rolling stock.

(The reduction ratio differs in Track Plans A, B, and C.)

(8) Reduction of maintenance cost

The adoption of long-welded rails extends rail life, also, the PC sleeper has a much longer life than the wooden sleeper. The long-welded rail, which has no rail joints and the PC sleeper, whose net weight is large, reduce track irregularity, extending the track maintenance cycle for ballast tamping and realignment.

Furthermore after rail replacement, old rails can be reused at other sections.

Thus, track maintenance cost is reduced, but the maintenance costs for telecommunications and signals increase with facility development.

(The reduction ratio differs in Track Plans A, B, and C.)

(9) Higher service grade

Shorter travelling time and improved operational punctuality and safety greatly enhance the grade of service.

In addition, the passenger information equipment improves passenger service. The wagon data processor system clarifies the arrival date and time of wagon, improving service for the wagon user.

Furthermore, the improved track contributes to a much more comfortable ride.

(10) Improved business efficiency

The speeded up information and data transfer, due to the improvement of the main communication network, telephone exchange and control telephone equipment and introduction of train radio, improves business efficiency. In addition, the arrangements for recovery after an accident and communication for track, etc. at times of emergency are smoothly made.

Table 5.6.1 Details of Effects by Item

Item		Effect	Track Plans A, B & C	Telecom Plans A & B	Signal Plans A & B	Train Control
1. Speed up	Express train Ordinary train Freight train	14 H → 10 H 19 H → 14 H 37 H → 25 H	o	-	o	-
2. Improved operational punctuality	Communication Reduction ratio of delay time	A: 90% B: 85%	o	o	o	o
3. Improved safety	Signal Reduction ratio of number of accidents	A: 75% B: 60%	o	o	o	o
4. Increased track capacity		60% UP	o	-	o	-
5. Effective rolling stock operation		16%	o	o	o	o
6. Reduced fuel consumption for operation	Track / Fuel Consumption	A: 6% B: 5% C: 4%	o	-	-	-
7. Decrease in amount of rolling stock damage	Track / Rolling stock Repair cost	A: 9% B: 7.5% C: 6%	o	-	-	-
8. Reduction of maintenance cost	Track / Maintenance cost	A: 100% B: 112% C: 147%	o	●	●	●
9. Higher grade of service			o	o	-	o
10. Higher business efficiency			-	o	-	o

(Remarks) The effect in Phases 1 and 2 is to be divided according to the train km or track length.
o Effect expected according to improvement
● Maintenance cost increase expected

5-7 Preparation for Facility Improvement

5-7-1 Track

(1) Manpower required for the track improvement works

The manpower required for the track improvement works are roughly as follows. The figure shows the number of workers per year for the total working period of nine years.

- Engineers 6
- Supervisors 24
- Skilled workers 209
- General workers 273

(2) Standards for laying long-welded rail

The long-welded rails are laid based on the following standard.

1) Standard of track structure

(a) New rail, or, if unavoidable, old rail but rather new, are to be used.

(b) As a rule, expansion switches are to be attached at both ends of the long-welded rail.

(c) If the use of buffer rail cannot be avoided, heat treated fish plates and heat treated bolts are to be used at the joints.

(d) In principle, the joints before and after the expansion switch should be welded.

(e) PC sleeper should be used.

(f) For ballastless bridges with long-welded rail, the rail fastenings and the contact point of sleepers and girder should have sufficient lateral strength and structure to prevent floating.

(g) As a rule, fastenings of rails on bridges should have no longitudinal resistance.

2) Standard set temperature

The set temperature of long-welded rail should be within the following range.

(a) Not lower than the expected maximum rail temperature by more than 35°C.

(b) Not higher than the expected minimum rail temperature by more than 40°C.

3) Laying method

(a) The track at the section for laying should be repaired beforehand to provide a good track condition and minimize the growth of track irregularities.

(b) Long-welded rail should be loaded and unloaded in a manner that they are not deformed or damaged.

(c) Before laying, the long-welded rail should be temporarily stored beside the main track in a manner that they are not subject to buckling.

(d) The laying should be carried out in a season when the change of temperature is small.

The jointing position of the tongue rail and the receiving rail, which together form an expansion switch is to be at the following place.

a) If the difference between the set temperature and midpoint temperature is 5°C or less, the stroke of the expansion switch should be adjusted at the centre.

b) If the difference between the set temperature and midpoint temperature is 5°C or more, the stroke should be adjusted at the rate of 1.5 mm/±1°C.

(3) Standard track works

For efficient and safe works, the standard of track works is established as follows:

- Rail replacement
- Turnout replacement
- Sleeper replacement
- Ballast increase
- Curve adjustment and re-alignment

For details, refer to the Appendix 5.6 'Method of Track Works'.

(4) Working equipment

As for the working equipment, the following are needed in addition to the existing equipment.

- Track motor car
- Rail changer
- Rail saw
- Rail drilling machine
- Rail carrier
- Rail bender
- Chill hole
- Expansion space adjuster
- Trolley
- Engine generator (portable type)
- Tie tamper (hand type)
- Track jack
- Low roller
- Rail wear measure
- Rail joint gauge
- Rail thermometer
- Steel tape (L = 30 m)
- Gauge measure and track leveller

5-7-2 Telecommunication and Signalling

(1) Organization

The installation of new equipment will be carried out under the following organization, with staff assigned for work supervision and plan.

Fig. 5.7.1 shows Organization of Installation.

	Signalling: Electronic block	Signalling: Electronic interlocking	Telecommunication: UHF	Telecommunication: Exchange	Telecommunication: Train radio	Telecommunication: Cable
Assistant inspector and senior fitter for work supervision	2	1	3	2	3	5
Junior fitter for work plan	2	1	1	1	1	1
Junior fitter for design negotiation	2	2	1	2	2	2
Assistant fitter for minor work	5	5	3	2	3	3
Total	11	9	8	7	9	11

Divisional Engineer (1) — Signalling (Electronic block, Electronic interlocking); Telecommunication (UHF, Exchange, Train radio, Cable)

Fig. 5.7.1 Organization for Installation

Source: Study Team

(2) Installation Standards

Rules governing the installation of telecommunication and signalling equipment should be provided, according to which the installation work should be carried out.

As for the rules of signalling equipment installation, the maintenance method is outlined in Chapter 7.

The installation rules are now provided, but new rules should be provided governing the electronic equipment to be newly provided for the careful handling of the equipment, when introduced.