5. Number of Arrival Tracks versus Arrival Train Frequency per Hour

By changing the minimum headway and time required for shunting locomotives to remove trains, the maximum value of train frequencies for arrival tracks is calculated (see Figure 2).

Assuming that the train diagram is set at an equal headway and that the shunting is done most efficiently, the present minimum headway t_1 = 5 min and shunting time t_2 = 5 min give an maximum value of 9 arrival trains per hour with 6 arrival tracks (a maximum 8 trains is handled presently).

The arrival tracks may be increased by two to 8 tracks, but only a maximum of 10 trains could be handled. Therefore, increasing the number of the tracks is not so effective by itself, but it will provide a great effect if it is accompanied by a reduction in the minimum headway as well as in the shunting time of DRCs.

Thus, for preparation of the diagram, it is shown that it will be effective not to have a lot of PCs arrive successively, but to have DRC trains inserted between arriving PCs.

6. Conclusion

To increase the number of arrival tracks, general trends in Figure 2 for reductions in shunting time passenger handling time, and headway are shown; no definitive answer is noticeable. Thus, an improvement plan was formulated and subjected to simulation (see Appendix 7.2.4).

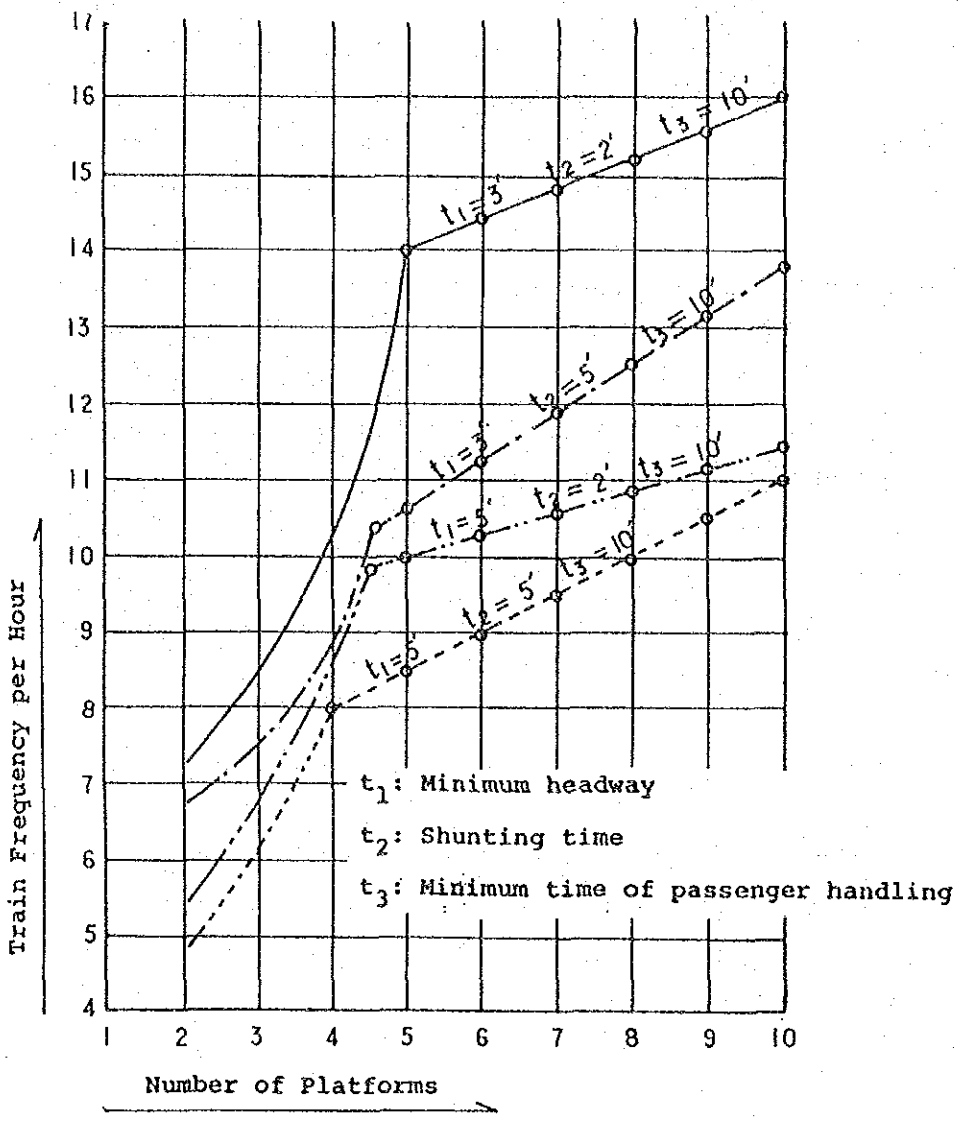


Fig. 2 Number of Platforms and Ultimate Number of Trains to be Handled

Appendix 7.2.4 Outline of the Simulation of the Number of Trains Arriving at Platforms in Bangkok Station.

1. Purpose of the Simulation

It is unclear as to whether it would be better to improve the present situation of Bangkok Station with respect to future increases in the number of train arrivals, or whether the station should be moved.

Therefore, simulations were carried out to calculate the capacities of the arrival platforms that are said to be approaching their limits.

The results of this estimation clarified that the improvement of Bangkok Station without relocation will result in it being able to handle the future increases in train arrival.

2. Arrival Platform Capacity Calculation Procedure

The following points are factors relating to the capacity of the arrival platforms.

1) Total number of trains arriving per day
2) Combinations of the various types of trains arriving
3) Shunting time
4) Minimum train intervals
5) Increase in the number of arrival platforms
   (utilizing some of the departure platforms as arrival platforms)

Of the above factors, if there is an increase in 1), there will also be an increase in the number of trains arriving per unit time. Accordingly, by performing simulations for such time zones, it is possible to calculate the critical limit of platform capacity.

Factor 2) takes into account that PC and DRC trains arrive at different times, and also handles passengers and shunting at different times. This means that combination of the two types of trains may produce differences in the number of trains that can be handled.

There can be an increase in platform track capacity, in which factor 3) is shortened, but other than using the departure track side for shunting, no suitable alternative can be thought of.

The reduction of factor 4) will have a large effect on increasing platform track capacity, but this is thought to require a large investment for signals, railway overpasses and other facilities; therefore, this measure should be implemented only after other measures have already been taken.

Increasing the number of arrival platforms (factor 5) is the most direct method for up-grading their capacity.

As a result, simulations were done for the present platforms and their current capacity calculated, and again for immediately after the implemention of the improvement plan with respect to arrival platforms.

Finally, platform track capacity was determined for the case where there is a minimum train operation interval after implementation of the improvement.

Fig.1 is a flow diagram of this calculation process.

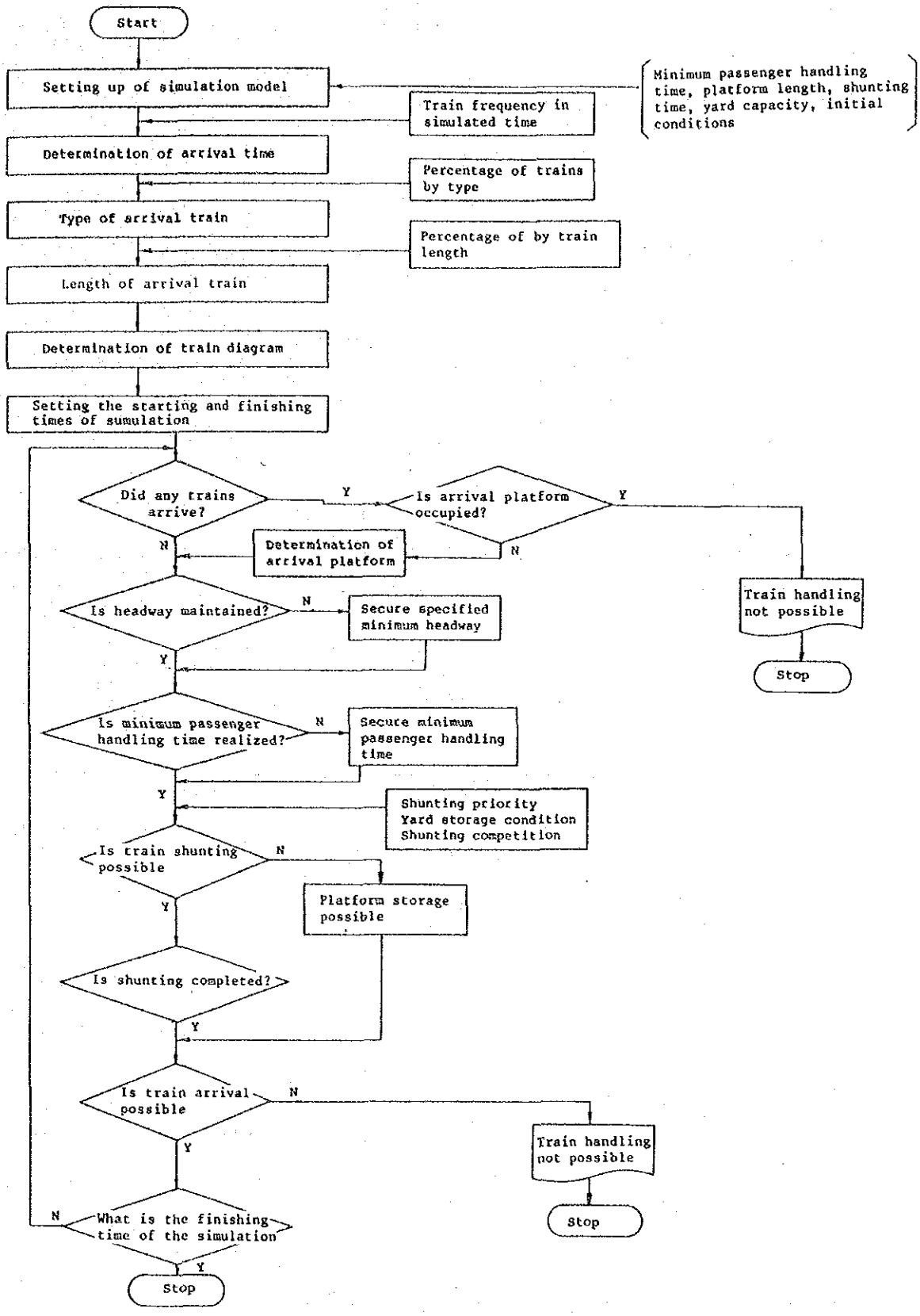


Fig.1 Flowchart of the Simulation of the Capacity of Arriving Trains

3. Conditions for the Current Simulation

(1) Diagram setting, determination of arriving train types and length

1) The number of trains arriving in unit time follows the Poisson's distribution

2) The percentages for the actual results in the calculated time zones are used for arriving train types and length. The occurrence results are assumed to be randomly distributed.

3) The number of trains arriving per unit time is verified by the performance ratios for the current state, and by calculations according to Poisson curves.

4) The train arrival interval within a unit time is random. However, the minimum time is taken to be five minutes (the current status).

Table 1 Length per Train Type

Train type	Section	Train length	Notes
PC	General	Short	
PC	General	Medium	
PC	General	Long	Short indicates 10 cars or less
DRC	General	Short	Medium indicates from 11 to 14 cars
DRC	Limited express	Short	Long indicates 15 cars or more

(2) Minimum train stopping time, shunting time

PCs are pulled by locomotives while DRCs are self-driven.

Table 2 Minimum Passenger Handling Times

Train type	Section	Minimum stopping time
PC	All	10 minutes
DRC	General	3 minutes
DRC	Limited express	8 minutes

Table 3 Time Required for Shunting of Arrival Trains

Track No.	PC			DRC
	Long	Medium	Short	
	Minutes	Minutes	Minutes	Minutes
1	4	4	4	3
2	4	4	4	3
3	5	5	5	3
4	5	5	5	3
5	5	2	2	1
6	5	2	2	1

Note: The platform-to-platform shunting time for a PC is assumed to be 10 minutes.

(3) Platform length, passenger car yard capacity

Long platforms can handle trains of both medium and short formations, while medium platforms can accomodate short trains. This idea also applies to the capacity of passenger car storage tracks.

Table 4 Platform Length Assumptions

Platform Track No.	Platform length
1	Medium
2	Long
3	Long
4	Long
5	Short
6	Short

Table 5 No. of Passenger trains that can be Stored in Yard

Effective length of passenger train storage tracks	Number of storage tracks
Long	3
Medium	9
Short	3

(4) Priority of arrival and shunting platforms

Table 6 Priority Arrival and Shunting Platforms

Train type	Arrival platform priority	Shunting platform priority
1.PC-long train	4,3,2,1,5,6	6,5,4,3,2,1 However, track Numbers 5 and 6 have the highest priority for shunting. The shunting of medium and short trains is conducted on the departure track side.
2.PC-medium train (1) No arrival of DRC for 15 minutes	6,5,4,3,2,1	
(2) Other cases	4,3,2,1,5,6	
3.PC-short train (1) Over 12min. interval until next train	6,5,4,3,2,1	
(2) Other cases	4,3,2,1,5,6	
4.DRC train	6,5,4,3,2,1	Performed immediately after arrival

The track for arrival trains is blocked for five minutes, with a priority over shunting.

PCs are taken by shunting locomotives into the passenger car yard for storage, while the self-driven DRC is stored elsewhere.

The arriving trains must be shunted more than once since the locomotives have to be separated.

(5) Obstruction to other platforms due to train arrival and shunting

Table 7 Obstruction to Other Platforms due to Train Arrivals and Shunting

Platform	Platform obstructed due to train arrival and shunting	Train arrival obstruction due to stopped trains (PC-long, medium)	Obstruction to other platforms due to shunting
1			2,3,4
2	1		1,3,4
3	1,2		1,2,4
4	1,2,3		1,2,3
5	1,2,3,4	6	6, (PC-long 1,2,3,4)
6	1,2,3,4,5	5	

4. Conditions for simulation after improvements

Only the points that differ from those mentioned in paragraph 3 will be described.

(1) Platform length, passenger train yard capacity

Table 8 Platform Length Assumptions

Platform	Platform length
0	Medium
1	Long
2	Long
3	Long
4	Long
5	Long
6	Long
7	Medium
8	Medium

Table 9 Number of Passenger Trains that can be Stored in Yard

Effective length of storage tracks	Number of storage tracks
Long	4
Medium	10
Short	3

(2) Priority of arrival and shunting platforms

Table 10 Priority of Arrival and Shunting Platforms

Train type	Arrival platform priority	Shunting platform priority
1.PC-long train	4,3,2,1,0,7,8,5,6	8,7,6,5,4,3,2,1,0 However, tracks numbers 5,6,7 and 8 have the highest priority for shunting. Shunting for medium and short trains is conducted on the departure track side.
2.PC-medium train (1)No arrival of DRC for 15 minutes	8,7,6,5,4,3,2,1,0	
(2)Other cases	4,3,2,1,0,7,8,5,6	
3.PC-short train (1) Over 12 minutes interval until next train	8,7,6,5,4,3,2,1,0	
(2) Other cases	4,3,2,1,0,7,8,5,6	
4.DRC train	8,7,6,5,4,3,2,1,0	Performed immediately after arrival

(3) Obstructions to other platforms due to train arrivals and shunting

Table.11 Obstructions for Other Lines due to Train Arrivals, Shunting

Platform	Shunting platform obstructed due to train arrival	Train arrival obstruction due to stopped train (PC-long)	Obstruction to other platforms due to shunting
0	1,2		1,2,3,4
1	0,2		0,2,3,4
2	0,1		0,1,3,4
3	0,1,2		0,1,2,4
4	0,1,2,3		0,1,2,3
5	0,1,2,3,4		6
6	0,1,2,3,4,5		5
7	0,1,2,3,4,5,6	8	8
8	0,1,2,3,4,5,6,7	7	7

5. Initial and Input Conditions

Data necessary for the initial conditions are as follows:

(1) Situation of the yard at the start of the simulation (number of storage tracks available)

(2) Number of trains per unit time

(3) Probability by type of train (PC, DRC)

(4) Probability by train formation (Long, Medium, Short)

Simulation will be conducted with the data for the above conditions for a period of 60 minutes, with the number of trains that can be handled, calculated and compared.

6. Results of Calculations

Table 12 shows all of the results of the calculations.

The following can be seen in the table.

(1) Current platform handling ability

The number of trains that can be handled at present is eight per hour. This number cannot be increased to nine.

(2) Improvement plan of platform handling ability

When there are nine platform tracks, with a five-minute headway for the minimum train arrival interval, it is possible to handle ten trains/hour, while there is a 50 percent possibility of not being able to handle 11 trains/hour.

In addition, it is possible to handle 12 trains/hour of the maximum track capacity of a line, if 50 percent of them are DRCs; therefore, the conversion to DRCs holds the key to increasing platform track capacity.

(3) Combining the improvement plan and a minimum train arrival interval of 3 minutes

In this case, the number of trains that can be handled is thought to be limited to 12 trains/hour, with extreme difficulties encountered if it becomes 13 trains/hour.

When there is a 3-minute headway, with a 65% DRC rise ratio, platform handling is still possible when the number of trains rises to the extreme value of 20 trains/hour.

Table 12 Relationship Between the Number of Arrival Trains and Whether Arrival is Possible

Number	Maximum number of arrival trains	Proportion of train type PC	Proportion of train type DRC	Simulation processing: Number of calculation	Simulation processing: Completed	Simulation processing: Not possible	Note
1. Current state							
	trains/hour	%	%				
1-1 8PD0	8	99	0	16	16	0	
1-2 9PD0	9	99	0	3	0	3	
1-3 9PD10	9	90	10	1	0	1	
2. Improvement plan (with 9 platforms, minimum train arrival time of 5 minutes)							
2-1 10PD0	10	99	0	14	14	0	
2-2 11PD0	11	99	0	4	2	2	Conditions
2-3 12PD0	12	99	0	1	0	1	PC arrivals
2-3' 12PD15	12	85	15	1	1	0	is 12
2-3" 12PD50	12	50	50	1	1	0	
3. Improvement plan (with 9 platforms, minimum train arrival time of 3 minutes)							
3-1 11PD20	11	80	20	1	1	0	Continuous PC arrivals 6
3-2 12PD20	12	80	20	4	2	2	6 —"—
3-3 13PD20	13	80	20	3	1	2	Impossible when continuous PC arrival is 6
3-4 14PD20	14	80	20	1	0	1	—"— 4
3-4' 14PD28	14	73	28	1	1	0	—"— 8
3-5 15PD35	15	65	35	2	0	2	—"— 4 or 9
3-5' 15PD40	15	60	40	1	1	0	
3-6 20PD65	20	35	65	2	2	0	

7. Maximum Number of Trains per Unit Hour

It is well known that their arrivals are random when the various modes of transportation have their various purposes, and their numbers per unit hour follow Poisson's distribution.

Fig. 2 shows the histogram of actual number train per hour in Bangkok Station and Poisson's curve. It can be said that the histogram follows the Position's distribution with a probability of about 80%.

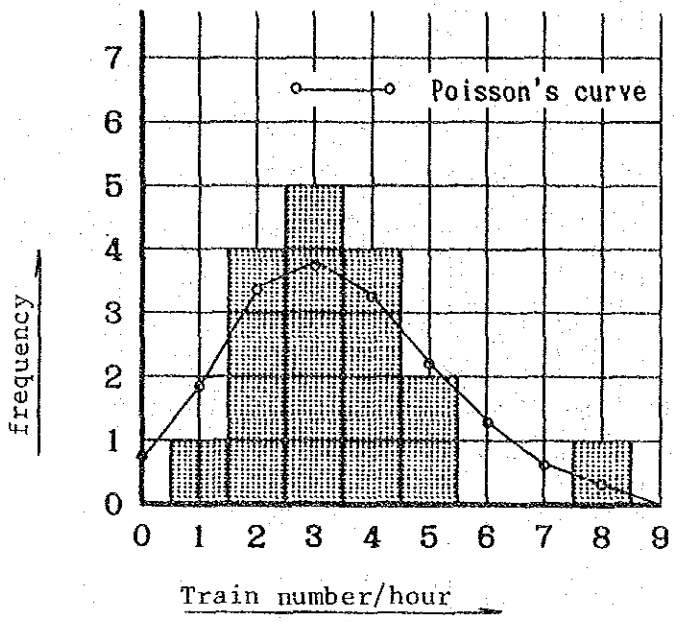


Fig. 2 Actual Number of Trains per Hour

It is also assumed that in the future when schedules for the Northern, Southern, and Eastern Lines are drawn up, in accordance with to the roles of each line and purposes of the express, rapid, and ordinary trains, these schedules will follow Poisson's distribution.

Accordingly, the relationship between the maximum number of trains per hour and the total number of trains per day will be as shown in Fig. 3, when the relationship is assumed to follow Poisson's distribution.

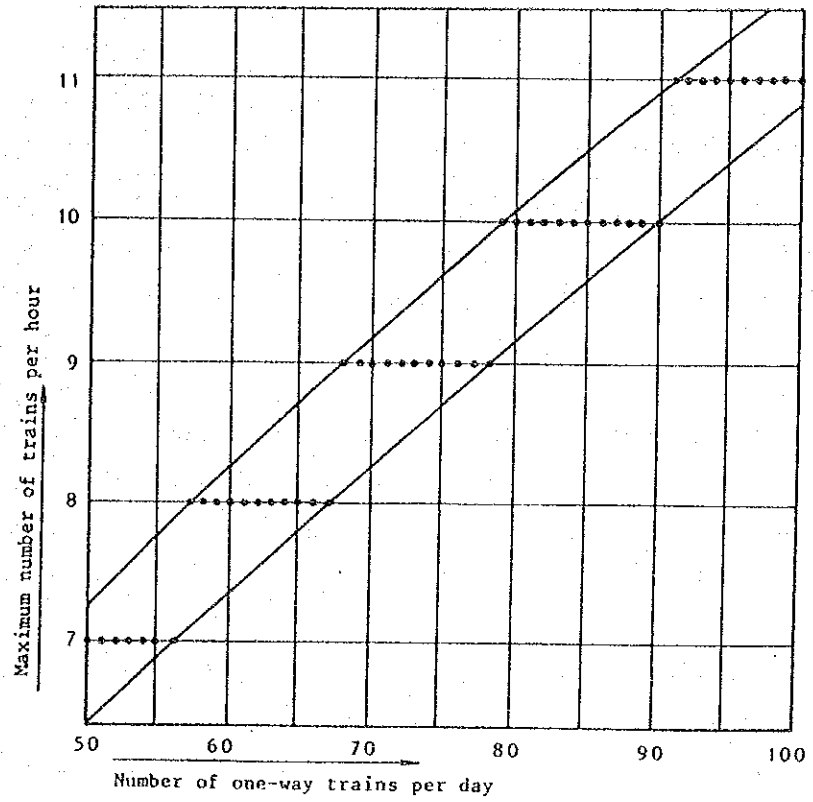


Fig. 3 The Total and Maximum Number of Trains Arriving per Unit Hour

When a diagram is drawn up, with an emphasis put on the roles of each section and train, the total number of one-way trains per day can be determined as follows from the maximum number of trains per hour.

Table 13: Assumed Number of One-way Trains per Day

Maximum number of trains per hour	Number of one-way trains per day
trains	trains
8	57 - 67
9	68 - 78
10	79 - 90
11	91 - over

When a parallel-type diagram is prepared for commuter and other trains, the graph shown in Fig. 3 will not be applicable.

8. Conclusions

The following can be concluded from the above. First, the number of trains handled is eight trains/hour with around 60 trains/day regarded as the limit under the present circumstances. This situation will not be able to cope with an increase in the number of trains in the future, and so urgent improvement is thought to be necessary.

If the number of tracks on which trains can arrive is increased to nine, then the maximum number of arrival trains per hour will be ten, and a new maximum of around 85 one-way trains/day will be possible. According to the estimates contained in this report, it seems possible to handle more trains up to the year 2006.

If it is necessary to increase the number of trains further, then it will be necessary to either greatly increase the number of DRCs, or to lessen the minimum arrival interval from five to three minutes; however, this is not thought necessary at the present stage.

Appendix 7.2.5 Effective Length of Arrival, Departure, and Passenger Car Storage Tracks

(Shown by bogie car length of 20 m)

Track	Track No.	Effective Track Length	Max. number of composed cars accommodated	Remarks
Arrival Track	No. 1	17^{B}	14^{B}	
	No. 2	16	14	
	No. 3	19	17	
	No. 4	18	17	
Arrival/ Departure Track	No. 5	11	△12	
	No. 6	11	△17	Inbound trains include 19B
Departure Track	No. 7	19	18	
	No. 8	15	△18	
	No. 9	17	△18	
	No. 10	17	△17	
	No. 11	12	△14	
PC Storage Track	No. 13	12	△14	
	No. 21	7	△18	Used up to 21-1
	No. 22	12	△16	
	No. 23	14	13	
	No. 24	16	16	
	No. 25	10	Reserve cars	
	No. 26	10	Reserve cars	Temporarily accommodating 12B
	No. 27	13	△14	
	No. 28	14	△17	

Note: 1. Numbers in △ show cars set over turnouts.

2. Train settings on turnouts on the main track are illustrated in Figure 1.

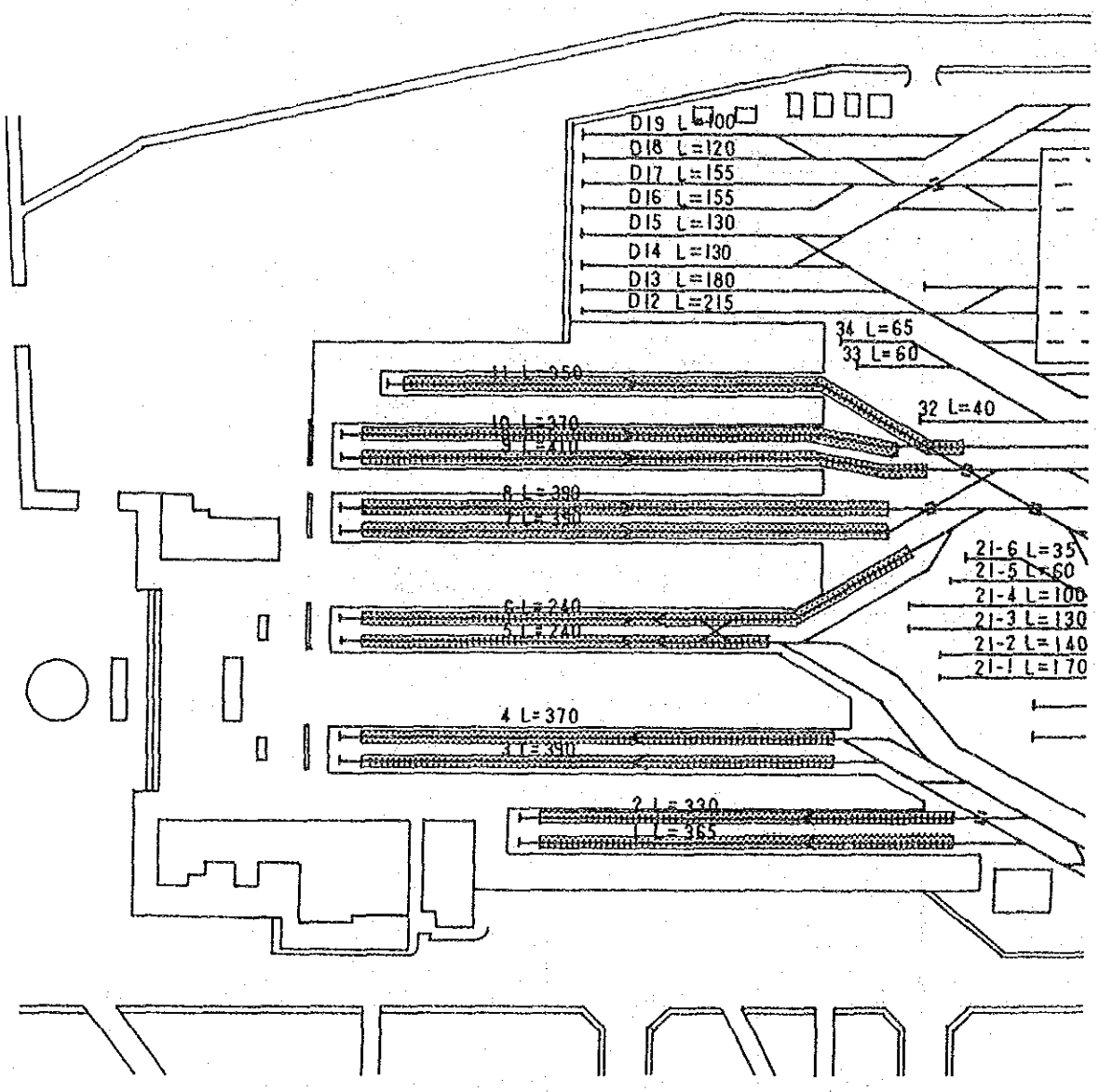


Fig. 1 Train Setting on the Main Track

Appendix 7.2.6 Number of Cars Actually Staying

(1) Survey of number of composed cars staying for 1 hour or more.

Places and Number / Hours	Arrival Track 4	Arrival/ Departure Track 2	Departure Track 5	PC Storage Track 7	Total 18
4 ∿ 5	0	0	2	0	2
5 ∿ 6	0	0	3	3	6
6 ∿ 7	3	1	3	6	13
7 ∿ 8	3	0	2	4	9
8 ∿ 9	3	0	3	4	10
9 ∿ 10	3	0	2	6	11
10 ∿ 11	3	0	4	5	12
11 ∿ 12	3	0	2	5	10
12 ∿ 13	3	0	2	4	9
13 ∿ 14	2	1	4	3	10
14 ∿ 15	2	0	4	3	9
15 ∿ 16	1	0	4	5	10
16 ∿ 17	1	0	3	4	8
17 ∿ 18	2	0	4	4	10
18 ∿ 19	2	1	3	3	9
19 ∿ 20	1	1	2	3	7
20 ∿ 21	1	0	3	2	6
21 ∿ 22	1	1	1	1	4
22 ∿ 23	0	1	2	0	3

(2) Survey of maximum stay in PC yard

Type	Number of Tracks	Actual Effective Length	Number of Cars Storable	Maximum Stay	Number of Cars Stored over Effective Length
Effective length 250 m or more	8	2,328 m	110 cars	6 tracks - 90 cars	No.22 4 cars No.28 3 cars
Effective length 200 ∿ 250 m	4	894	46	4 tracks - 46 cars	-
Effective length 150 ∿ 200 m	1	172	8	1 tracks - 8 cars	-
Effective length 150 or less	8	852	37	6 tracks - 44 cars	No.21 11 cars
Total	21	4,246	201	17 tracks - 188 cars	

Note: Engine running track No. 14 is not included.

Appendix 7.2.7 Condition of Train Operation at the Branch Point of the Northern and Eastern Lines

1. Crossing of the Northern Line's up Train Tracks by down Trains of the Eastern Line

The minimum headway that trains are operated at is five minutes. In the case that down trains of the Eastern Line cross the up tracks of the Northern Line at Yom Ma Rat , Table 1 shows the condition of Yom Ma Rat five minutes before and after the crossing time of the trains.

As seen in the table, eleven of the seven trains cross the up track of the Northern Line within a time span of five minutes and compete with up trains of the Northern Line. In addition, it is necessary to consider a certain period of waiting time at Makkasan, since the Eastern Line is a single track line. In consideration of an increase in the number of trains, in the future, it is desirable to have down trains cross the Northern Line immediately before an up train of the Northern Line.

Next, we will review the condition of the continuous operation of down trains. Three trains operate continuously on the Eastern Line within five minutes after a Northern train, and three trains operate continuously on the Northern Line within five minutes after an Eastern train. Of these, the former has little influence on the diagram of the Eastern Line, because the Northern Line is a double-track system, but the latter greatly influences the down train diagram of the Northern Line due to such reasons as the timing of the crossing of the Northern Line by Eastern trains, operation conditions of opposing trains, dependent on the single track system of the Eastern Line, and frequent stopping of Eastern trains at Yom Ma Rat , which relies on the open/close condition of crossing, etc.

Such a condition in the continuous operation of trains will be seen more frequently as the number of trains increases in the future. It is expected that Eastern down trains crossing the up tracks of the Northern Line will have a more serious influence on the train diagram of other lines in the future.

To solve these problems, it is desirable to provide a sidetrack having the effective length of one train between the branch point of Northern down trains and the Eastern Line and to design the Northern up track crossing and facilities so that a route for Northern down trains opens up after an Eastern down train enters this sidetrack.

Table 1 Condition of Yom Ma Rat Crossing Five Minutes before and after Eastern down Trains Cross the up Track of the Northern Line

Before and after crossing time	No. of crossings of Eastern Line trains	Northern Line is continued to Eastern Line	Eastern Line is continued to Northern Line	Wait at Makkasan
Immediately before or after the passage of Northern trains	1	1	-	-
Immediately after the passage of a Northern train	2	1	-	-
Immediately after the passage of a Northern train	4	-	1	2
Crossing of other trains not related	4	1	2	1
Total	11	3	3	3

2. Temporary Run of Eastern up Trains on the Northern up Track

Table 2 shows the condition of the up tracks of the Northern Line 10 minutes before and after the entering of Eastern up trains.

An Eastern train scheduled to enter the concurrently used section of track, immediately before or after a Northern train, normally stops at Makkasan Station for time adjustment.

To maintain the capacity of the arrival tracks of Bangkok Station at its specified level, it is necessary to keep the time interval between arriving trains at a minimum headway of five minutes. However, it seems difficult to make this adjustment when starting trains from Makkasan Station.

The headway of trains, especially, is expected to become smaller in connection with an increase in the number of trains in the future. Therefore, this adjustment would become more difficult.

This siding is necessary for Bangkok Station in order to operate trains punctually, secure accurate arrival of trains and utilize shunting and platform capacities fully.

Table 2 Conditions of Eastern up trains entering up tracks of Northern Line

Entering time of Eastern train	Within 5 min.	Within 10 min.	Total	Wait at Makkasan
Enter before or after passage of Northern train		1	1	
Enter after passage of Northern train	2	1	3	1
Enter before passage of Northern train	5	-	5	2
Other trains having no influence	-	-	2	-
Total			11	3

Appendix 7.2.8 Improvement of Interlocking Machine and Signals

It is desirable to change the conventional interlocking machine and improve the signals by using color lights of the three-light system (displaying G, Y and R).

The interlocking machine is provided with various locking devices (route locking, sectional route locking, detector locking, stick locking, section locking, indication locking and approach locking). At present, approach locking is not provided, and must by all means be installed for securing train safety.

Note: Approach locking locks points so that when a train proceeds, in accordance with the proceed display of a signal, into a certain section in the rear of a signal, or when a train has already proceeded into that certain section in the rear of the signal, the train is unable to switch the points until the train enters inside the signal or after the elapse of a considerable amount of time after the signal displays a stop signal.

Presently, 1st class electric relay interlocking is provided. However, the operation is such that there are departure/arrival point push buttons provided at each signal, and by depressing such a push button a route is formed and the signal made to indicate proceed. To switch the respective points independently, the push button of a point and the release button of the Common Points are depressed.

Route formation along the main track is done according to the following method.

(1) Confirming that there are neither trains nor cars present in the route to be formed, the departure point button is depressed first, then the objective point button depressed. By this, the related electric pneumatic switch machine is switched in the direction of the route, and the signal at the departure point made to indicate proceed.

(2) When the train proceeds in to the signal area and short-circuits the first track circuit, the signal indicates stop.

(3) As the train passes the respective track circuits, the points included in each of the track circuits have their locks released.

(4) When the train completely enters the arrival point track circuit, the operation is back to (1).

Formation of Shunting Route

Shunting signals are installed but are not used.

(1) Confirming that there are neither trains nor cars present in the route to be formed, the points are independently turned to form the route.

(2) Confirming that the points on the route have been switched, an OK sign is given to a yard man.

(3) Upon arrival to the objective point, the operation is back to (1).

The present interlocking machine and operation are greatly dependent on the judgment of men. This is suitable where there are smaller numbers of turnouts and frequencies of trains, but it is still dangerous and there should be greater headway as a safety measure.

What type of interlocking device is desirable is dependent on further examination, but when the selective route type is chosen, for example, it is as follows.

By turning the start point lever (S31) down and depressing the push button of the arrival point (No. 3 track), the route is formed and the signal indicates proceed. As the train proceeds into the signal area and the departure point lever (S31) is restored or the start point lever (S31) turned down and the push button of the arrival point (No. 1 track) depressed, the route is opened to track No. 1 and the signal (S31) indicates proceed when the train has passed over the related track circuit of track No. 3 previously formed.

In this way, before the train proceeds completely into track No. 3, the next route formation can be prepared. That the route is formed when the signal indicates proceed means completion of the route locking. On account of the high security and fast route formation, the headway is reduced to 2 minutes in some sections. However, for sorting tracks with large a number of turnouts, the circuit becomes complex and costly. Thus, there are some cases where both the selective route type for main tracks and route level type for sidings are used. Studies like the above are also concerned with turnouts in the effective length and will have to include examinations of such factors. It is also necessary to examine the way shunting signals are used.

Appendix 7.2.9 Effective Length of Main Track

(Note) Δ : decrease

Track No.	Existing effect length	Planning	Increase/ decrease	Remarks
	m	m	m	
-1 (New)	-	290	290	
0 (New)	-	290	290	
1	365	330	Δ35	
2	330	350	20	
3	390	420	30	
4	370	420	50	
5	240	315	75	
6	240	315	75	
7	390	390 (290)	0 (Δ100) ( ); arrival	
8	390	390 (290)	0 (Δ100) train only	
9	410	410	0	
10	370	370	0	
11	350	310	40	
12 (New)	-	310	310	

2. Effective Length of Siding in Passenger Car Yard

Track No.	Existing effective length	Planning	Increase/ decrease
	m	m	
13	225	220	0
14	Engine Running Track		
15	370	230	Δ140
16	105	105	0
17	130	225	125
18	220	325	105
19	270	310	40
20	270	290	20
21	150	150	0
-1	170	40	Δ130
-2	140	20	Δ120
-3	130	35	Δ 95
-4	100	80	Δ 20
-5	60	55	Δ 5
-6	35	35	0
22	260	165	Δ 95
23	280	225	Δ 55
24	340	280	Δ 60
25	220	280	60
26	220	280	60
27	285	350	65
28	300	380	80
Total			Δ160

3. Effective Length of Siding in DRC Depot

Track No.	Existing effective length	Planning	Increase/ decrease
D_1	140	110	Δ 30
D_{12}	215	355	140
D_{13}	180	320	140
D_{14}	130	260	130
D_{15}	130	250	120
D_{16}	155	265	110
D_{17}	155	260	105
Total			715

(1) The 1st changeover work

1) Track

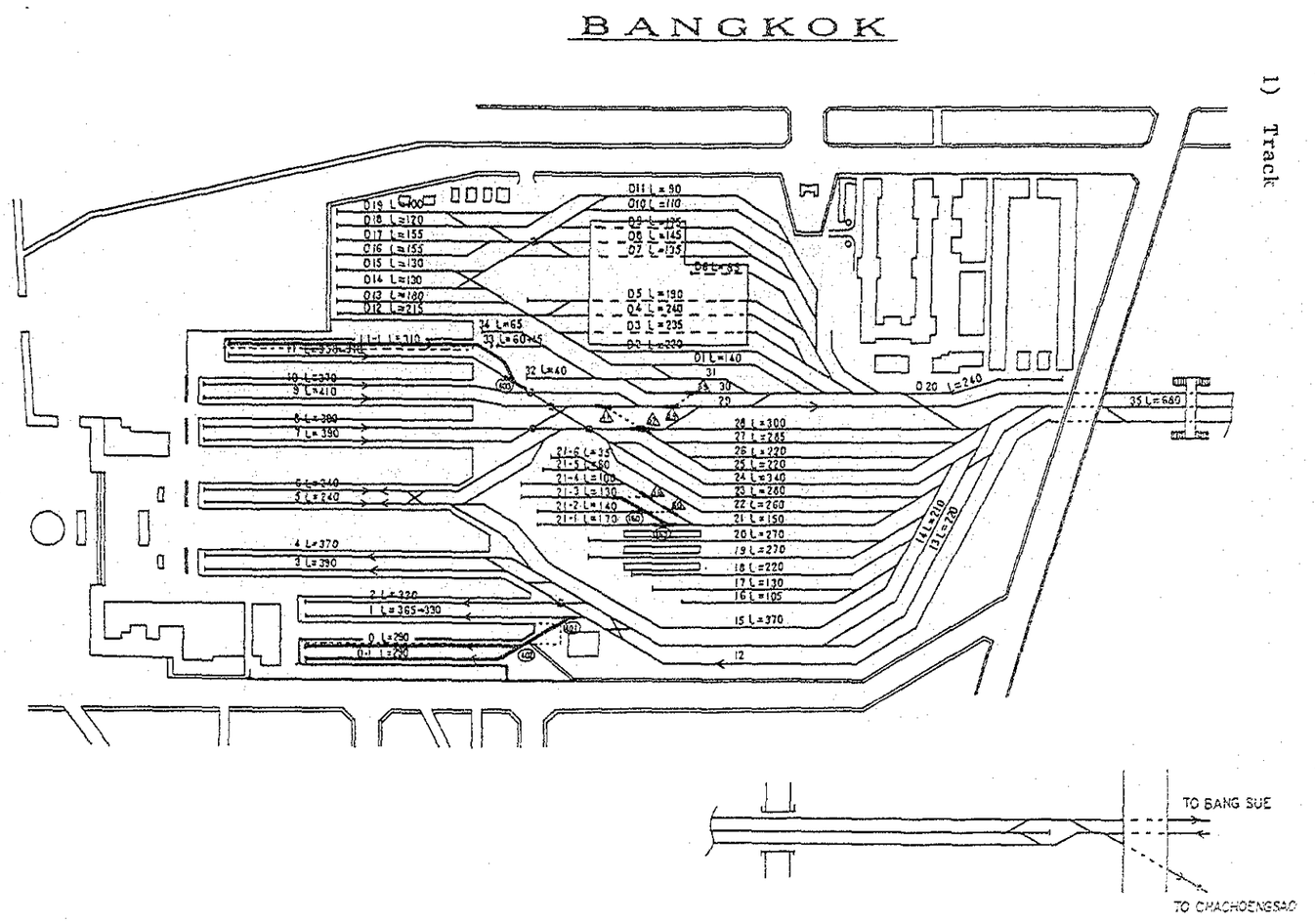


Fig. 1 The 1st Changeover Work Diagram (Track)

1-1 Installation of two additional arrival tracks and one departure track

(1) Introduction of turnout (401) into arrival track and assemblage of (402)

track No. 0: New installation of track No. 0-1

(2) Introduction of turnout (403) into departure track and new installation of track No. 11-1

1-2 Removal of subroute at departure track side

(1) Removal of turnouts △54 and △59

(2) Removal of turnouts △41 and △52 (Retain those at the yard side)

1-3 Reconnection of passenger car storage track and track No. 21

(1) Introduction of turnout (165)

(2) Introduction of turnout (160) and connection of (165) and track No. 21-3

(3) Removal of turnouts △56 and △60

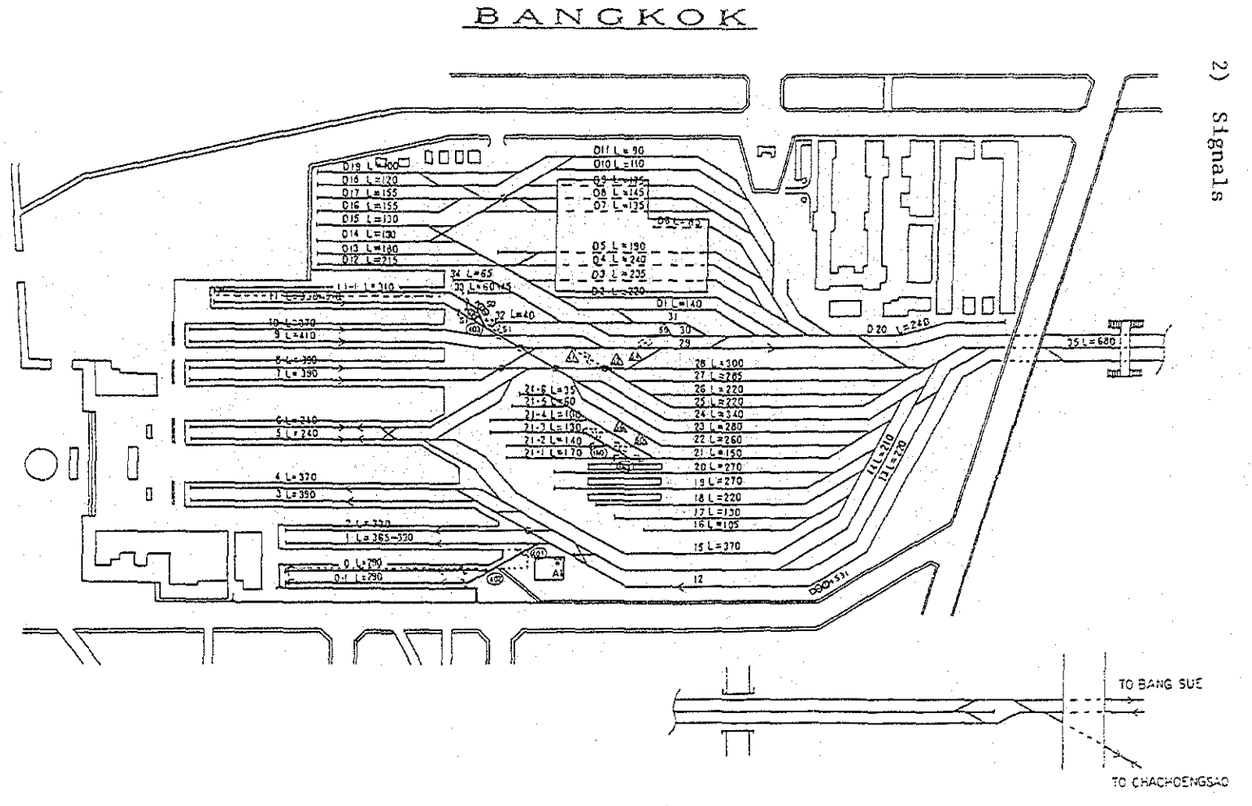


Fig. 2 The 1st Changeover Work Diagram (Signals)

In connection with the installation of two additional arrival tracks and one departure track and reconnection of the passenger car retention track and track No. 21, the signalling facilities should be modified as follows.

(1) Preliminary tests should be conducted. (Existing interlocking devices are modified)
Modification of board
Change-of-line connection

(2) Use of shunting signals is prohibited.

(3) Install new electric switch machines in turnouts (401) and (402), which are to be introduced respectively.

(4) Install a new track circuit on tracks No. 0 and No. 0-1 respectively.

(5) Install a new electric switch machine in turnout (403), which is to be introduced.

(6) Install a new starting signal, S-1, on track No. 11-1.

(7) In connection with the installation of new track No. 11-1, starting signal S-1 should be removed because of interference.

(8) Exchange a number display unit incidental to signal S32.

(9) Remove electric switch machines from turnouts △54, △59, △41 and △52, which are also to be removed.

(10) Reinstall the electric switch machines of turnouts △56 and △60 in turnouts (160) and (165), which are to be introduced.

(11) In connection with the turnouts to be removed or introduced, the composition of track circuits must be properly changed.

(12) Interlocking tests should be made.
Track circuit test
Railroad switch conversion test
Signal display test

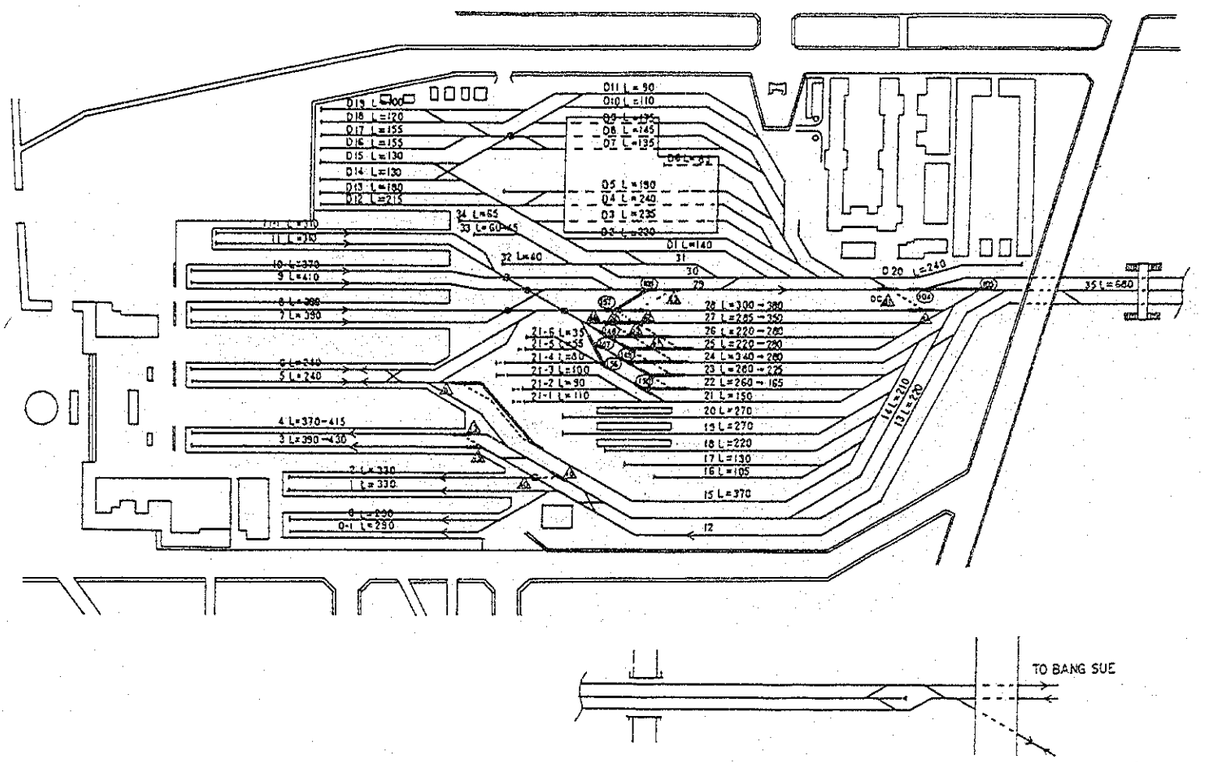


Fig. 3 The 2nd Changeover Work Diagram (Track)

2-1 Connection change of passenger car retention track group

(1) Turnouts (147) and (156) are introduced and both units connected together.

(2) Turnout (150) is introduced and connected to track No. 22.

(3) Turnout (149) is introduced and connected to tracks No. 23 and No. 24.

(4) Turnout (148) is introduced and connected to track No. 25. Turnout △61 is removed and track No. 26 connected to (148).

(5) Turnout △59 is removed and turnout △46 connected to track No. 27.

(6) DSS △52 is removed.

2-2 Changing incoming and outgoing routes of DRCs

(1) Turnouts (157) and (165) are introduced and both units connected together.

(2) Turnouts △62 and △63 are removed.

(3) Turnouts (104) and (105) are introduced and both units connected together.

(4) DC △91 is changed to a one-sided open type turnout.

(5) Turnout △94 is removed.

2-3 Preparation for improvement of arrival track

(1) Turnout △8 and track No. 15 are changed into a new route.

(2) Turnout △48 is removed.

(3) Turnouts △13 and △19 are removed.

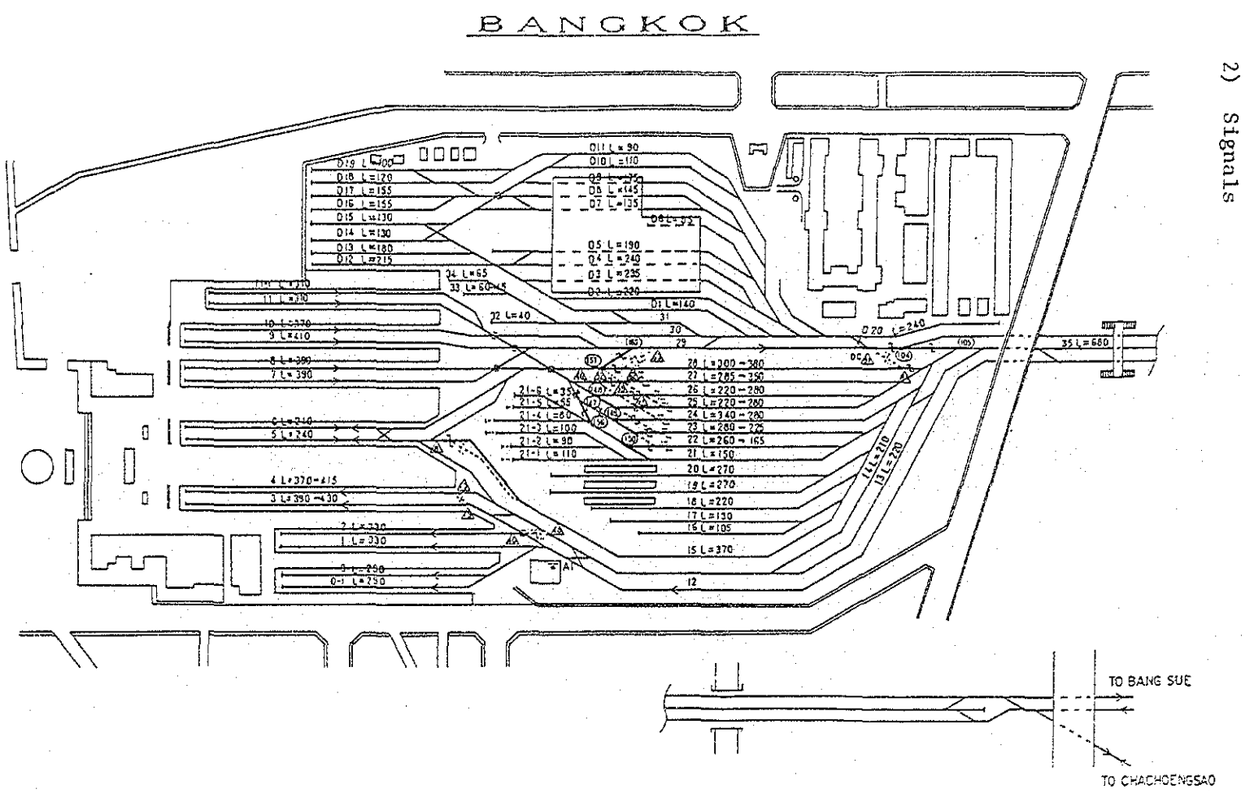


Fig. 4 The 2nd Changeover Work Diagram (Signals)

Signalling facilities should be modified in regards to the reconnection of passenger car retention track groups, changing of the incoming and outgoing routes of DRCs, and preparation for improvement of arrival tracks.

(1) Preliminary tests should be conducted. (Existing interlocking devices are modified.)
Modification of board
Change of wire connection

(2) Electric switch machines are newly installed in turnouts (147), (156), (150) and (149), which are to be introduced.

(3) The electric switch machine of turnout △59 is removed and installed in turnout (148), which is to be introduced.

(4) Electric switch machines of turnouts △61, △46 and △52, which are to be removed, are taken out.

(5) Electric switch machines of turnouts △62 and △63, which are to be removed, are taken out and installed in the newly introduced turnouts of (165) and (157).

(6) An electric switch machine is newly installed in turnouts (104) and (105), which are to be introduced.

(7) An electric switch machine is newly installed in turnout (91), which is to be introduced.

(8) The electric machine switch of turnout △94, which is to be removed, is taken out.

(9) Electric switch machines are taken out from turnouts △8, △48, △13 and △19, which are to be removed.

(10) Track circuits are removed or modified in conjunction with the removal or introduction of turnouts.

(11) Interlocking tests should be made.
Track circuit test
Railroad switch conversion test
Signal display test

(3) The 3rd changeover work

1) Track

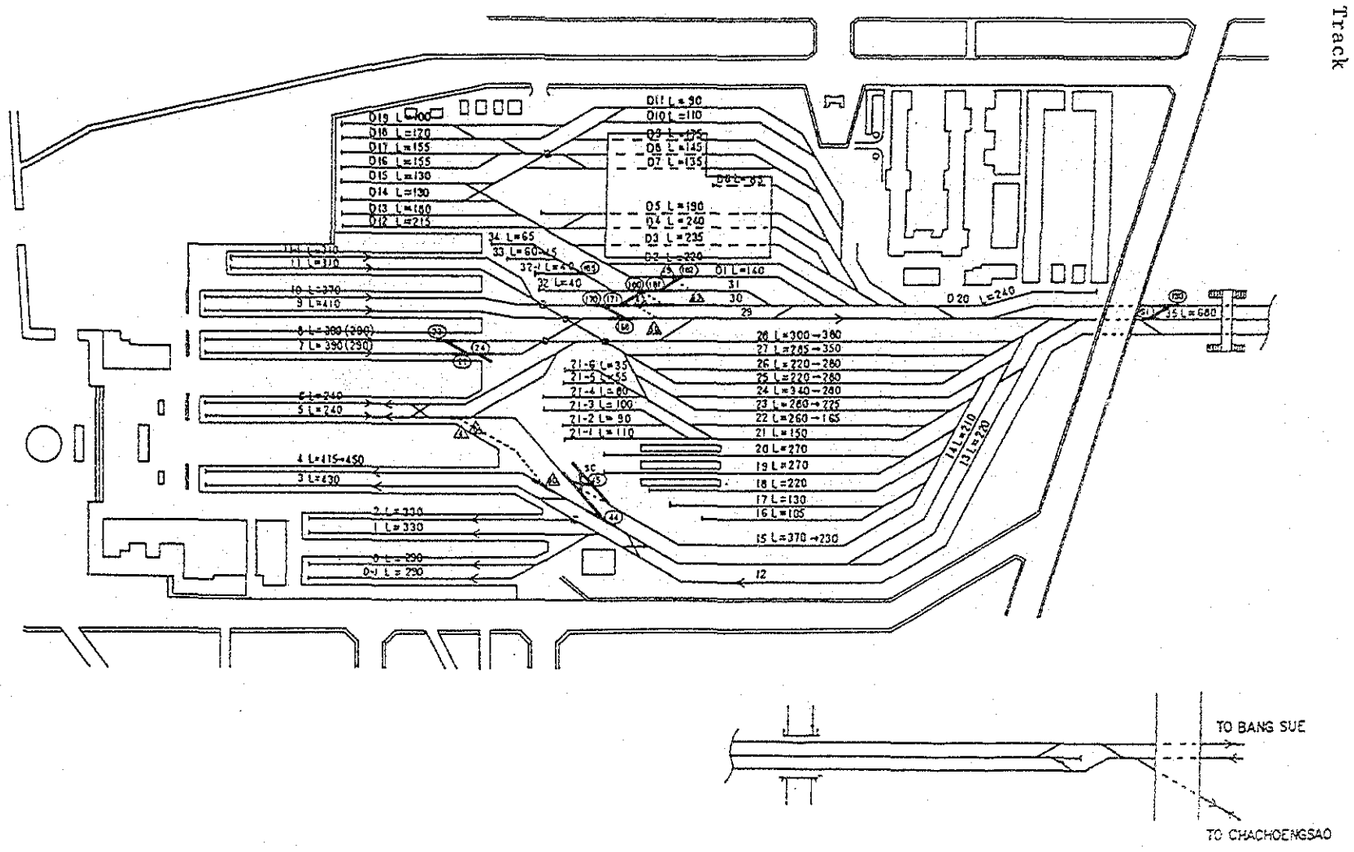


Fig. 5 The 3rd Changeover Work Diagram (Track)

3-1 Preparation for the conversion of track No. 7 and No. 8 into arrival/departure tracks

(1) Turnout (44) is introduced.

(2) SC (45) is introduced and (44) connected to △8.

(3) Turnouts △4 and △30 and track between them are removed.

(4) Turnouts (22), (23) and (24) are introduced.

3-2 Changing incoming and outgoing routes of DRCs

(1) Turnouts (170) and (168) are introduced and both units connected together.

(2) Turnout △50 is removed and track No. 10 connected to track No. 30.

(3) Turnout △43 is removed and (171) and (180) introduced and connected together.

(4) Turnouts △49 and △53 are removed and (181) and (182) introduced and connected together.

(5) Turnout (185) is introduced and track No. 32-1 newly installed.

(6) Turnouts (190) and (191) are introduced and connected together.

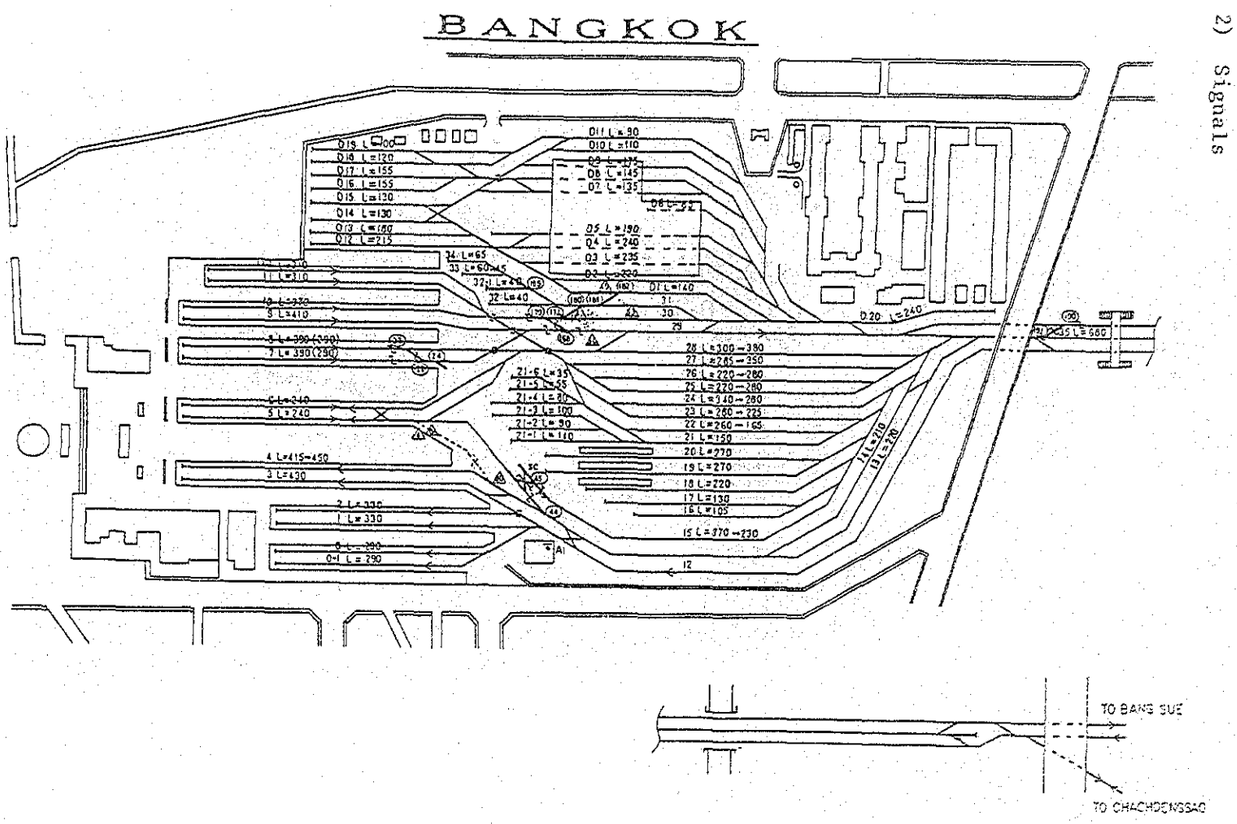


Fig. 6 The 3rd Changeover Work Diagram (Signals)

Signalling facilities should be properly modified in connection with the preparation for conversion of track No. 7 and No. 8 into arrival/departure tracks and the changing of the incoming and outgoing routes of DRCs.

(1) Preliminary tests (Existing interlocking devices are modified)
Modification of board
Change of wire connection

(2) Turnout (24) is introduced and shall be of a keylock.

(3) Electric switch machines are installed in SC (45) and turnouts (44), (22) and (23) introduced.

(4) Electric switch machines are taken out from turnouts △4 and △30, which are to be removed.

(5) Electric switch machines are newly installed in turnouts (170) and (168), which are to be introduced.

(6) The electric switch machines of turnouts △50 and △43, which are to be removed, are taken out and installed in turnouts (171) and (180), which are to be introduced.

(7) Electric switch machines are newly installed in turnouts (190) and (191), which are to be introduced.

(8) Track circuits are removed or changed in composition in conjunction with those turnouts which are removed or introduced.

(9) Interlocking tests should be made.
Track circuit test
Railroad switch conversion test
Signal display test

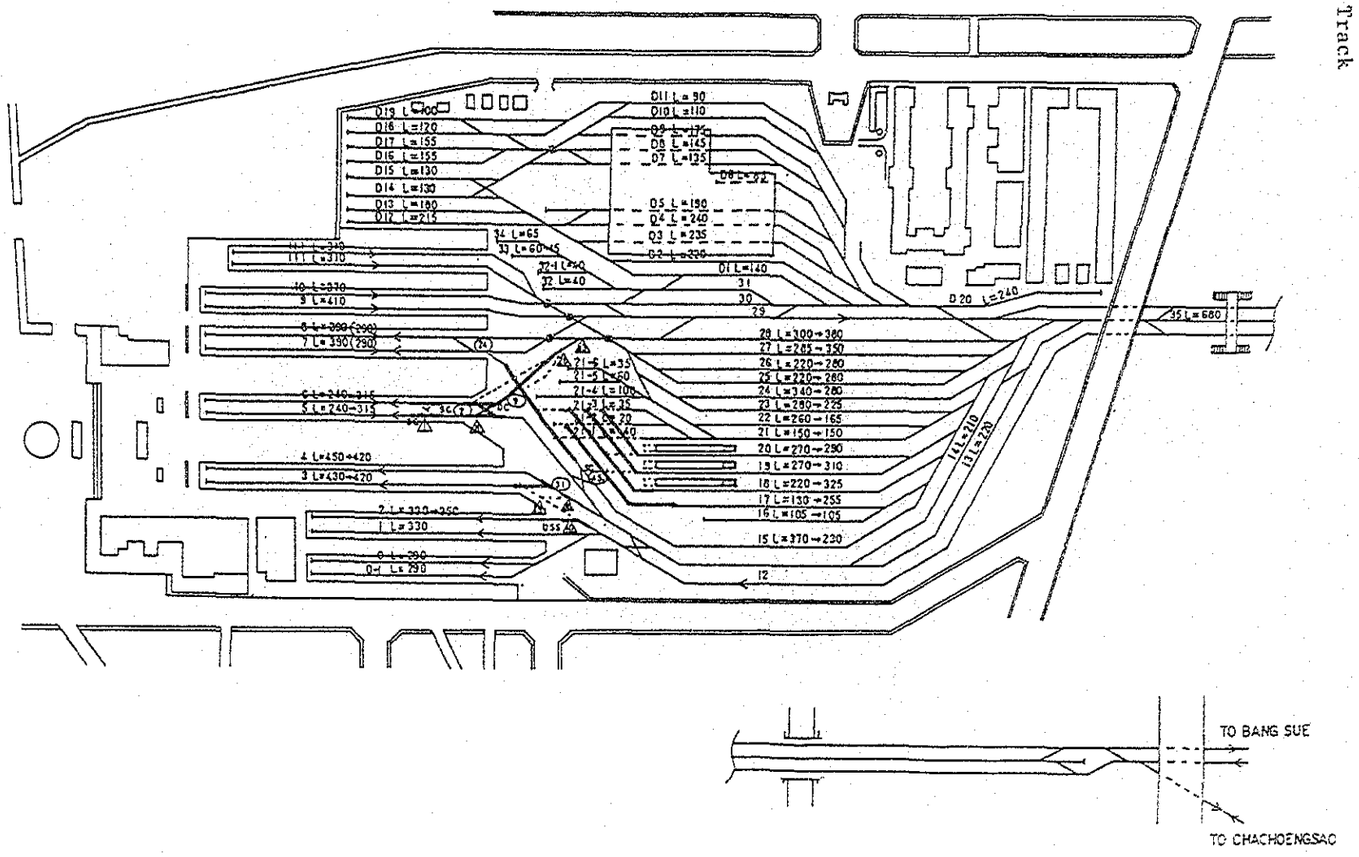


Fig. 7 The 4th Changeover Work Diagram (Track)

4-1 Extension of effective length of track No.3 and No.4

(1) Turnout (31) is introduced and connected to track No. 3.

(2) Turnouts △29, △38 and DSS △40 are removed.

4-2 Extension of effective length of track No.5 and No.6

(1) Turnouts △8 and △28 are removed, and SC (2) and DC (9) introduced and connected to △33.

(2) SC (1) is removed.

(3) Turnout (24) is connected to SC (45).

4-3 Extension of washing track

(1) A washing stand is newly installed about 40 m in front of track Nos. 19 and 20, and the existing one, which is located about 40 m in back of the track, is removed.

(2) The effective length of track Nos. 20-1, 20-2 and 20-3 is reduced respectively.

(3) The effective length of track Nos. 17 through 20 is extended respectively.

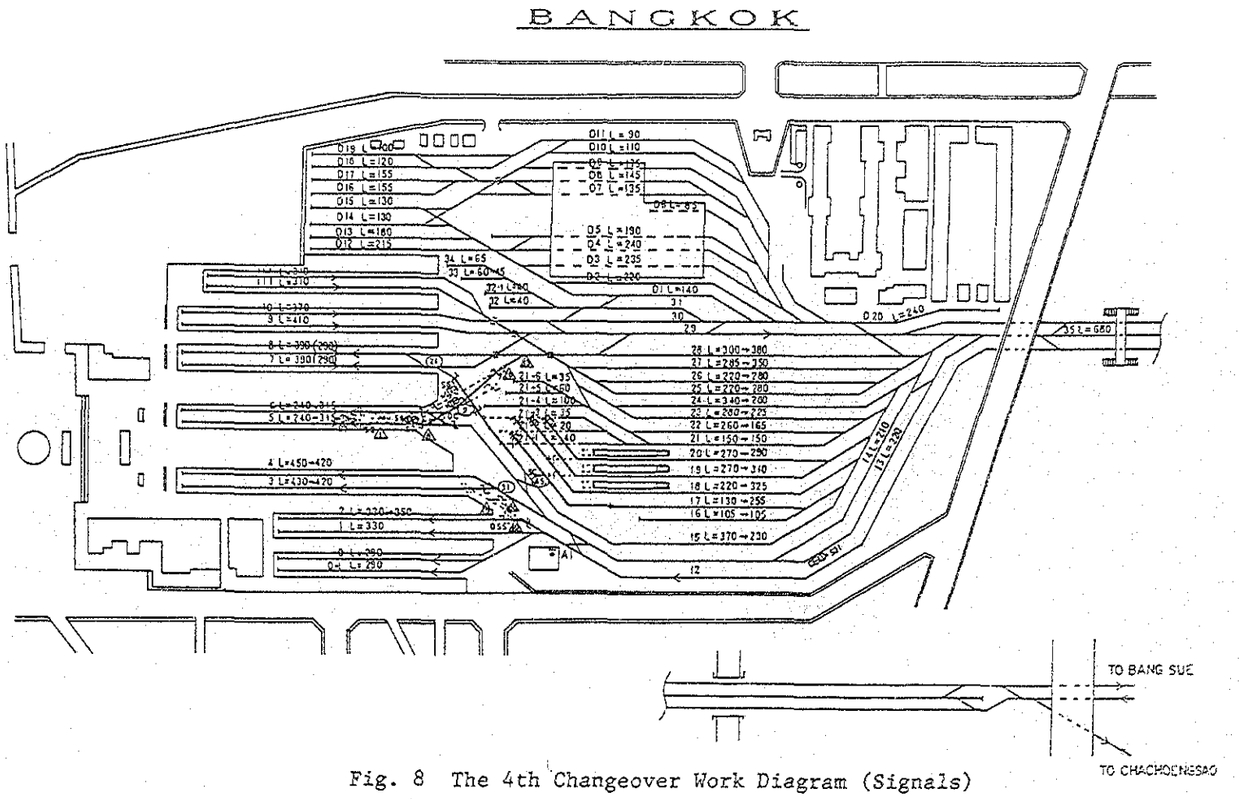


Fig. 8 The 4th Changeover Work Diagram (Signals)

In connection with the extension of the effective length of track Nos. 3, 4, 5 and 6, signalling facilities should be modified accordingly.

(1) New interlocking devices are installed in signal boxes in advance, and the main body of each interlocking device tested alone. (New relays are also used.)

(2) The electric switch machine of turnout △30, which is to be removed, is taken out and installed in turnout (31), which is to be introduced.

(3) Electric switch machines are taken out from turnouts △29 and △40, which are to be removed.

(4) Electric switch machines are taken out from turnouts △8 and △28, which are to be removed.

(5) The electric switch machines of each SC △1 to be removed are taken out and reinstalled in each SC (2) to be introduced.

(6) Electric switch machines are newly installed in turnout △24 introduced previously.

(7) Track circuits are removed or changed in composition in connection with the removal or introduction of turnouts.

(8) The locations of the following signals should be changed in line with the changes in the effective track length.
S6, S7

(9) The number display equipment attached to S31 is remodeled and used for Route 10. Road display units are installed in S32 and S35.

(10) Since shunting signals are prohibited, they are discarded and shunting display units (line display system), 1 K through 10 K, newly installed.

(11) The existing interlocking devices are discarded and interlocking tests should be made by using new interlocking devices.
Track circuit test
Railroad switch conversion test
Signal display test

Appendix 7.3.1 Yard Facilities in Mae Nam Station

Freight Facilities

Track	Number of Tracks	Effective Length(m)	Track Number
Freight arrival and departure	4	680 - 710	1 - 4
Sorting	7	140 - 640	10, 11, 13, 22 and 22-1 - 22-3
Passing	3		12, 14, and 15
Freight handling (Corn)	5	120 - 510	7-2, 7-4, 8-2,12-1 and 15-1
Freight handling (Petroleum)			
Caltex	2	140 and 290	7 and 7-1
Esso	7	120 - 380	5, 19 - 21-1
Shell	7	100 - 790	6, 6-1, 18, 18-1, and 25 - 25-2
PTT	9		
Bangkok old port	1 unit		S 1
Bangkok new port	1 unit		S 2

Appendix 7.3.2 Comparison of the New Shortcut and its Alternative

1. Proposed shortcut

The newly proposed shortcut between Mae Nam main and Port stations connects point B at the main station and point C on the port line. This is described below in the comparison with the existing line.

(1) The line capacity between Mae Nam and Chitralada

The line capacity between Mae Nam and Chitralada is presently 36 trains a day as shown in Appendix 7.3.3, almost fulfilling its capacity of 38.

Shunting work between the main and port stations is done at present on the main line on the Makkasan side, where a train is drawn-out and reversed.

This interferes with the drawing up of a train schedule, yard work diagram and hence operation of cars between Bang Sue and Mae Nam. A proposed new line can eliminate the interference between shunting work and trains running on the main line. In addition, yard work may be greatly simplified because Mae Nam station could make a shunting work schedule to its liking.

(2) Reverse operation at the level crossing

Seven round-trips of general cars are shunted a day between the main and port stations. During the shunting work, these cars are pulled because of the long distance (5km) and the existence of many level crossings between the two stations. This necessitates a push operation for both ways between point A and the main station (shown in Figure 1), and hence reverse operation on the Makkassan side of Point A. This is at the level crossing where the main line and Rama IV Road cross. In view of the long shunting over the level crossing caused by reverse and dangerous push operations towards the level crossing, these operations should be abolished. In fact, the proposed line can make it possible for trains in the yard to be operated by a pull operation, which would ensure safety and cause no interference with the Rama IV Road.

(3) Reduction of yard work time

Time required for yard work on the proposed line between points B and C would be less than that on the line between A and C (including reverse operation) by about 10 minutes for one round shunting operation. For seven round operations a day, 70 minutes could be saved. In addition, whenever Mae Nam station requires it, cars could be shunted to the port station independent of freight trains running on the main line between Mae Nam and Bang Sue, as was described in (1). Three locomotives for shunting assigned to Mae Nam yard could be reduced to two if yard work time is shortened and simplified and becomes independent of trains on the main line.

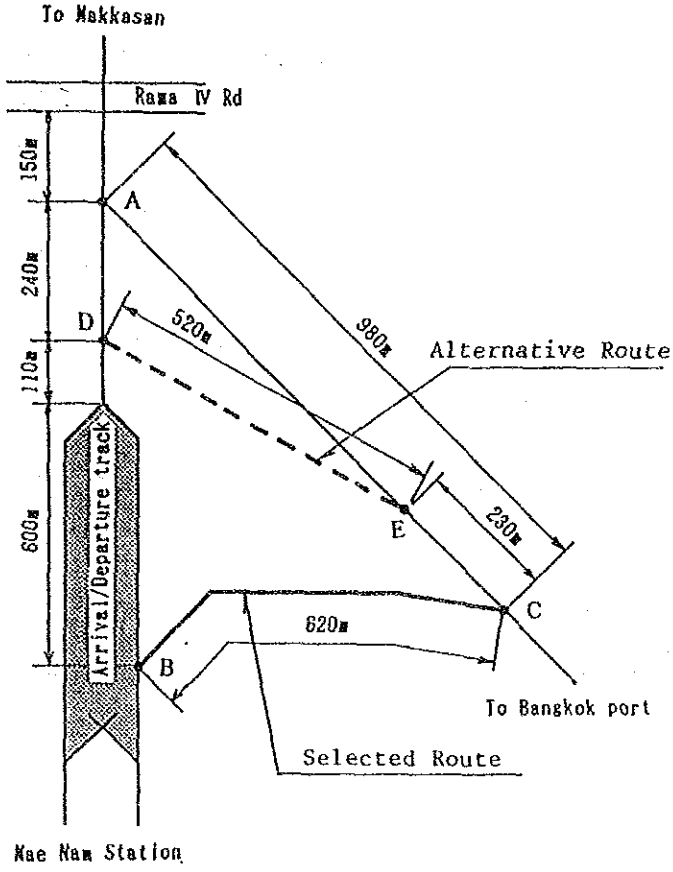


Fig. 1 Mae Nam Station Short-cut Route

(Note) Reduction of one shunting locomotive means a reduction of 30 to 40 personnel (see Appendix 7.4.3, Table 5). In rationalization, assignment of shunting locomotives to yards is worth thorough examination.

(4) Grade separation from Rama IV Road

In the study of grade separation from Rama IV Road, point A (in Figure 1) will be a sharp slope. Since a reversing operation on a sharp slope is very dangerous, the top of the slope should be made level so that trains can be safely reversed there. Furthermore, for a train to go up or down a steep slope, air valves that feed air to the continuous brakes to prevent the train from running must be attached to each car. Therefore, a proposed new line is necessary for building the grade separation.

2. An alternative plan

Although the proposed route has several advantages as stated above, the site seems to be very hard to purchase because of its urban location. Route D ~ E has come up as an alternative plan for Route B ~ C (see Figure 1). The features of Route D ~ E in comparison with Route B ~ C are as follows.

(1) The line capacity between Mae Nam and Chitralada

As to shunting work between the main and port stations, trains will be reversed on the main line between Mae Nam and Makkasan as they are now. Hence, the improvements expected for Route B ~ C described in 1. (1) cannot be obtained.

(2) Reverse operation at the level crossing

Trains are reversed at point D, instead of point A. Point D is located 400m from the Rama IV Road, generally greater than the length of trains operated in the yard. Shunting work, therefore, would be almost no hinderance to traffic at the level crossing.

(3) Reduction of yard work time

Five minutes will be saved for one round shunting operation by changing the reversing point from A to D shown in Figure 1, or a savings of 35 minutes for seven round operations a day. But the alternative plan (Route D ~ E) necessitates shunting work be done in the intervals between freight trains running on the main line between Bangkok and Mae Nam. This limitation is an obstacle to a study to reduce the number of locomotives for shunting.

(4) Grade separation from Rama IV Road

If the present level crossing is changed to a grade separated crossing, the point where trains are reversed will be located on a steep slope. Hence, the same measure will be needed as that in the case in which a grade separated crossing is built without changing present conditions.

(5) Comparison of construction costs

Table 1 Construction costs for two routes

(unit: mil. Bahts)

Route	Construction costs
Proposed Route B ~C	56
Alternative Route D~ E	14
Difference	42

(6) Conclusions

The construction cost for the proposed route is far greater than that of the alternative route. Yet Route B ~ C is recommended because:

- o Reverse operation on the main line can be eliminated.
- o This will increase line capacity between Makkasan and Mae Nam.
- o Shunting work will become possible between Mae Nam station and Bangkok port at the station's linking of trains running on the main line.
- o A yard work diagram will become easy to draw up.
- o The number of shunting locomotives can be reviewed due to reduced shunting work time.
- o Even in case of a grade separated crossing at the Rama IV Road in the future, there is no need for a train to be reversed on the steep slope.

Appendix 7.3.3 Shortage of Line Capacity between Mae Nam and Chitralada

Since there is a shortage of line capacity between Mae Nam and Chitralada, the arrival and departure trains are restricted at Mae Nam station.
When the line capacity of the section between Mae Nam and Chitralada is calculated as a single section having no other difficulties, it is given as below.

Line capacity $C = \frac{1,440}{t + s} \times 0.6$

$= \frac{1,440}{20 + 2.5} \times 0.6 = 38$ times

t : Average operating time between stations
s : Train handling time
0.6 : Line utilization efficiency

The present train operation is 36 times (efficiency 95%), with a margin of only 2 more operations.
However, because of the crossing with the passenger track at Makkasan (Figure 1.1), capacity falls below 38. Thus, it is considered that the line is utilized one hundred percent or more.
Upon improvement as shown in Figure 1.2, line capacity increases as given below.

Line capacity $C = \frac{1,440}{t + s} \times 0.6 \times 0.7$

$= \frac{1,440}{10 + 2.5} \times 0.6 \times 0.7$

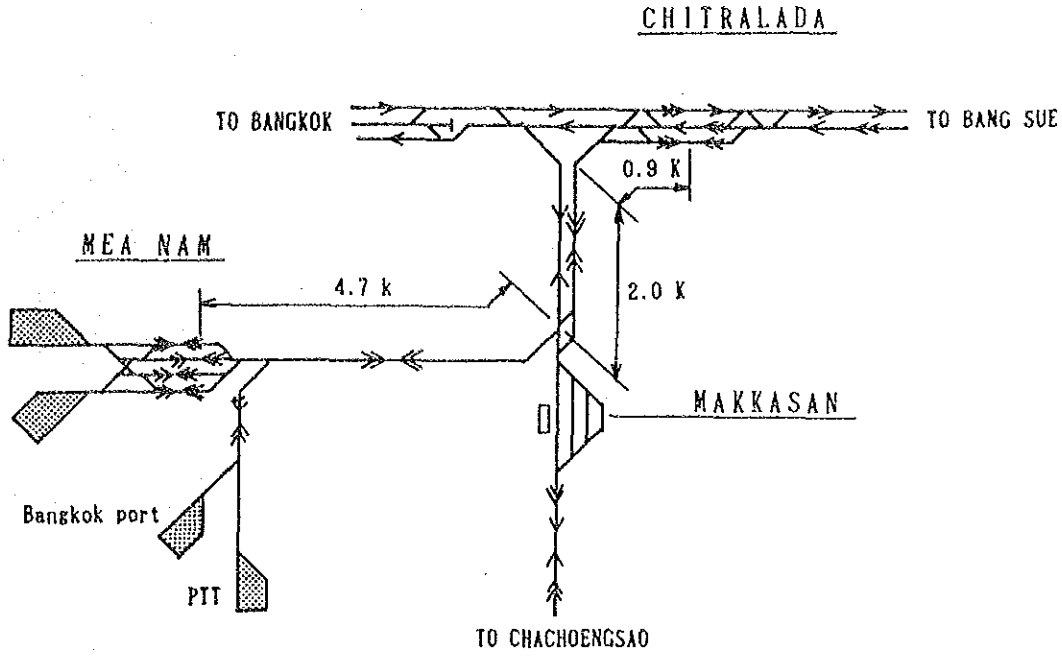
$= 47$ times

0.7 : Line utilization efficiency

(Raised to 0.7 for joint use with passenger trains)

By this, the diagram of trains arriving at and departing from Mae Nam will be improved greatly. Also, the delay of freight trains due to the shortage of line capacity will be reduced.

Present



Improvement Plan

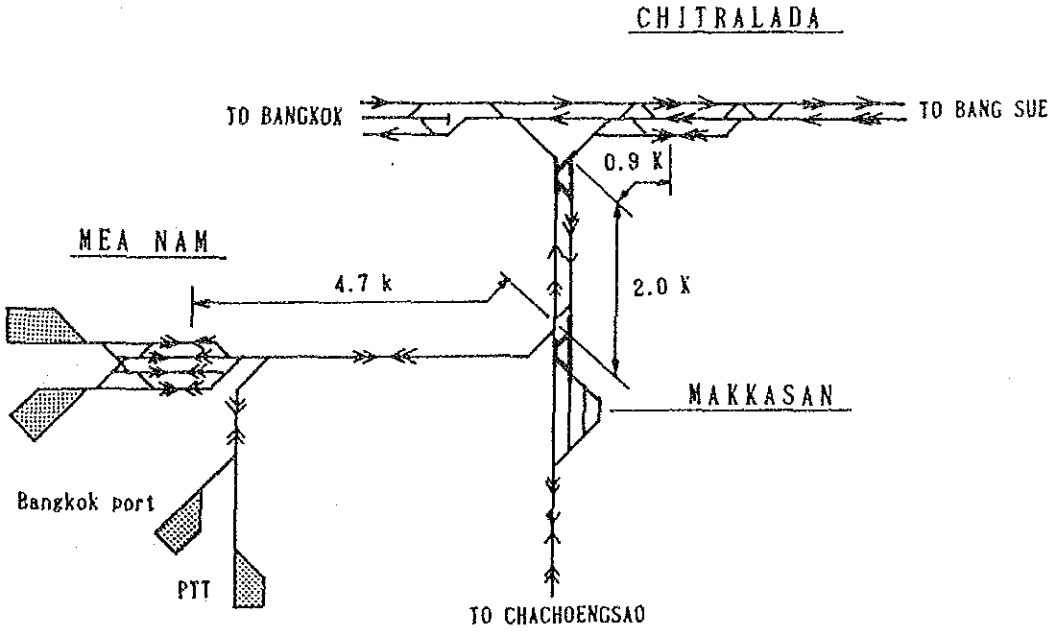


Fig. 1 Makkasan-Chitaralada Double-track Plan

(1) The 1st changeover work (Track)

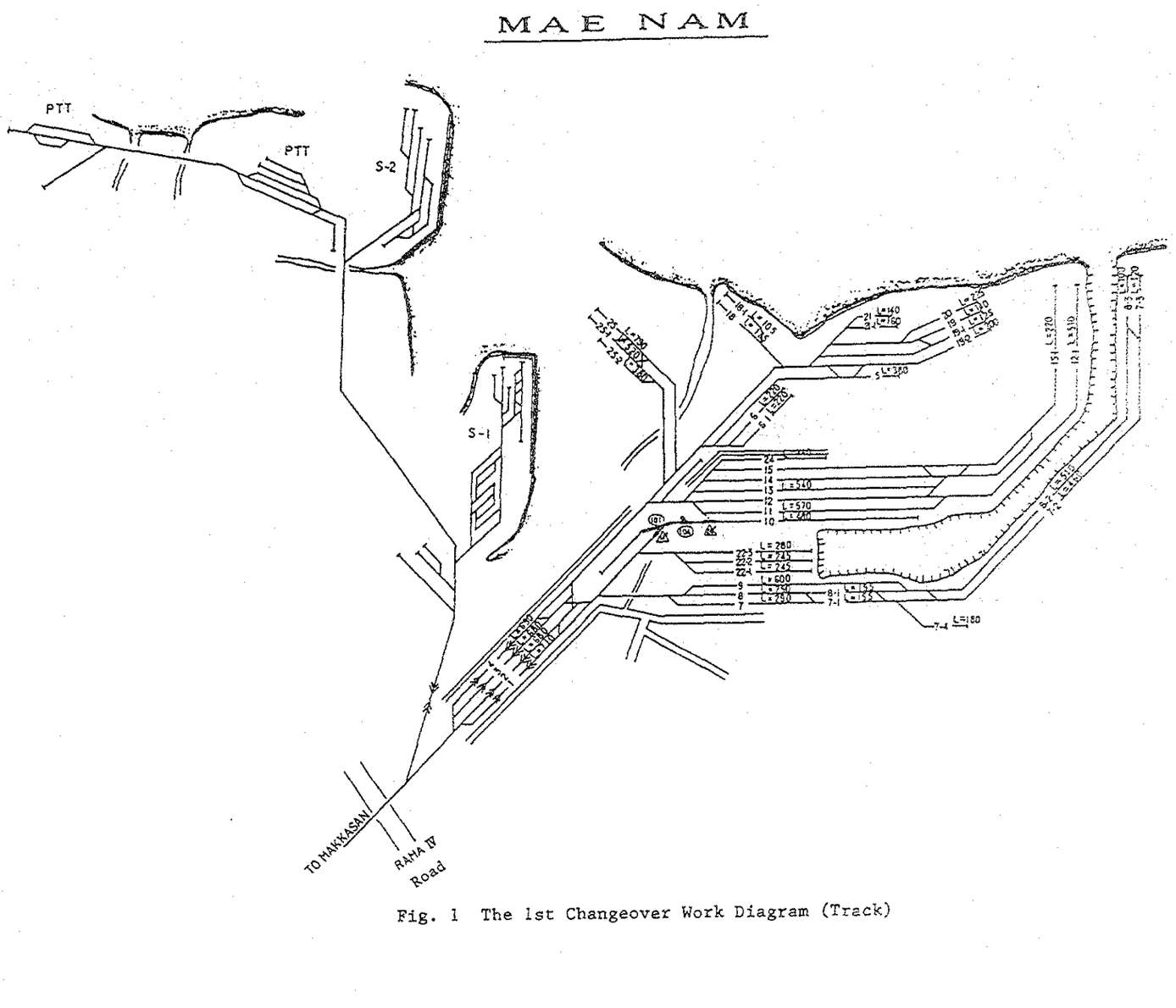


Fig. 1 The 1st Changeover Work Diagram (Track)

1-1 Relocation of Track No. 10

Turnout (14) is removed, (101) and (104) introduced, and 24' removed.
Connect track No. 10 to turnouts (101) and (104).

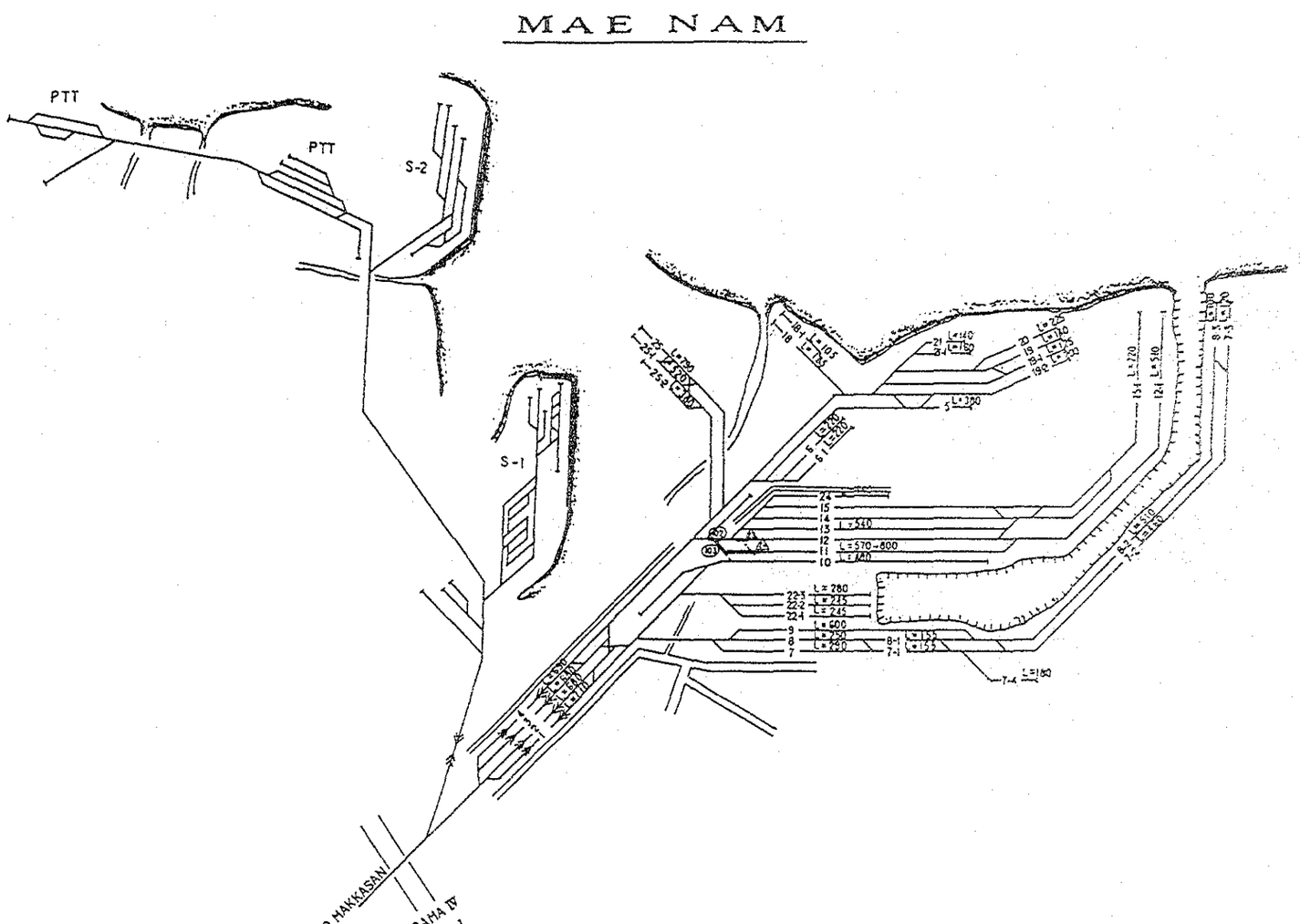


Fig. 2 The 2nd Changeover Work Diagram (Track)

2-1 Relocation of Track No. 11

Turnout (102) is introduced, (103) assembled, and △23 and △24 removed. Connect track No. 11 to (102) and (103).

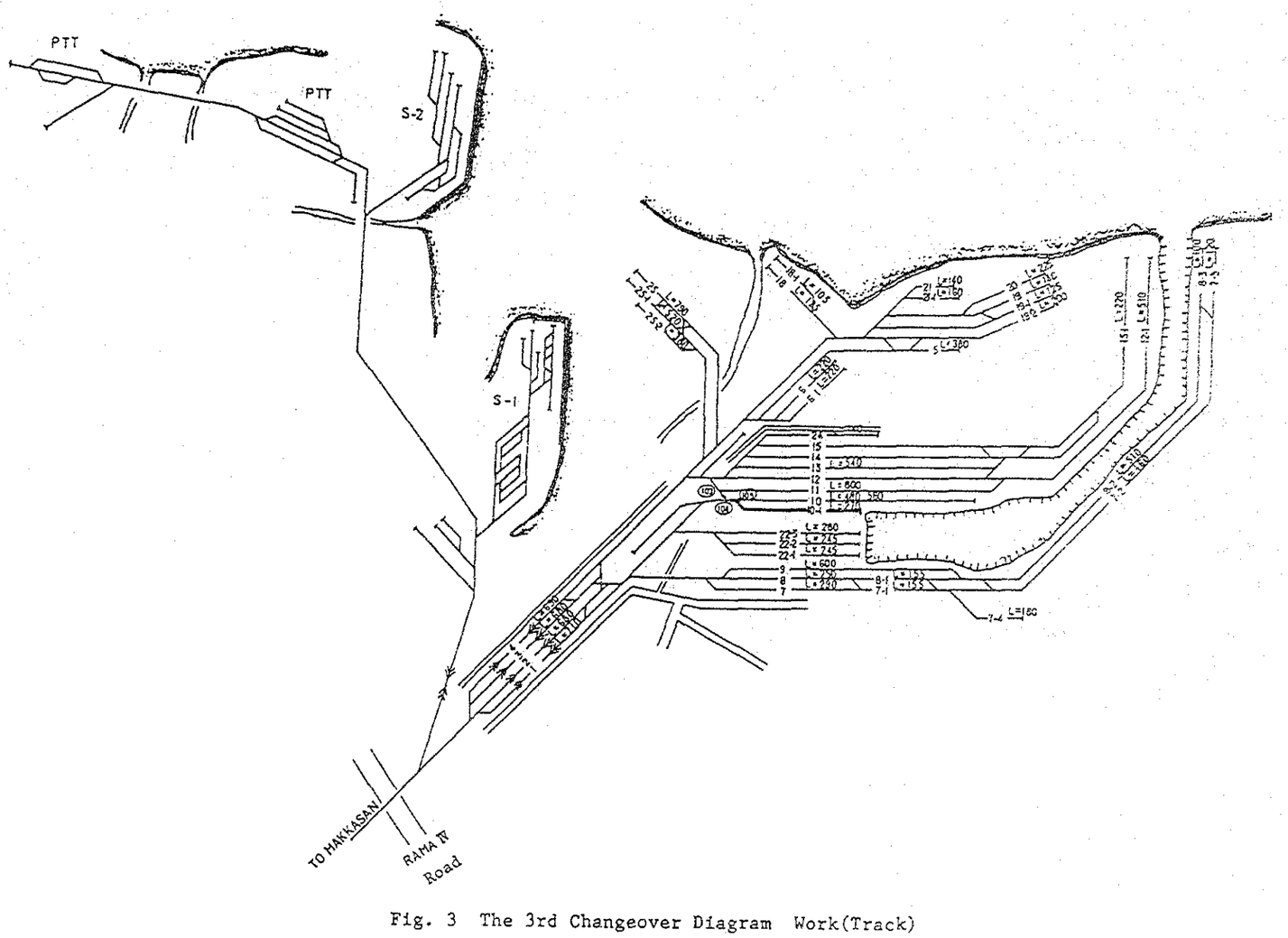


Fig. 3 The 3rd Changeover Diagram Work(Track)

3-1 Installation of Track No. 10-1

Turnout (105) is introduced, and track No. 10-1 installed while turnouts (103) and (104) are connected.

Appendix 7.4.1 Yard Facilities in Bang Sue Station

1. Passenger Facilities

Track	Platform	Number of Tracks	Effective Length (m)	Track Number
Passenger arrival and departure	Yes	3	410 - 800	2 - 4
Freight arrival and departure	No	1	580	1
DRC storage	No	8	280 - 390	5 - 6, and 14 - 19
Freight car storage	No	6	200 - 400	8 - 13
Engine run - round	No	1		1

2. Engine Depot Facilities

Track	Number of Tracks	Effective Length (m)	Track Number
DL inspection and repair	6	180 - 330	D-1 - D-6
DL storage	6	150 - 330	D-7 - D-12
Wheel inspection and grinding	8	120 - 480	D-13 - D-20
Passenger and freight car storage	11	70 - 220	D-21 - D31

3. Freight Car Yard Facilities

Track	Number of Tracks	Effective Length (m)	Track Number
Arrival (up)	3	390 - 590	AT-1 - AT-3
Engine run - round	1		AT-4
Arrival (down)	3	450 - 530	AT-5 - AT-7
Departure (down)	5	490 - 550	DT1-DT4, and CY1
Departure (up)	1	430	DT5
Sorting	22	490 - 670	CY-2 - CY-23
Rearrangement and draw-out	2	490 and 490	Z-1 and Z-2
Receiving	4	420 - 490	FT-1 - FT-4

Appendix 7.4.2 Matters Related to Bang Sue Yard Improvement Plan

(1) Handling of marine container trains

When the Eastern Seaboard Program is completed, the marine containers that will arrive and depart to/from this station will be handled at the marine container base adjacent to the freight draw-out tracks (No. CS6), and customs inspections will be performed here. And so container loading/unloading and pre-loading work of arrival and departure trains can all be done under the management of customs officials. This is to say that the arrival and departure tracks for marine containers are planned to be newly constructed separately except for other than securing a route for marine container trains, it is not necessary to incorporate anything else into this plan.

(2) Handling of special cement trains

The amount of freight handled by Bang Sue Yard at present is approximately 1,000,000 tons/year (for fiscal 1985), and of this, cement trains accounted for approximately 800,000 tons/year, constituting 80% of the amount handled.

The majority of these cement trains are used to transport the six special trains (periodic operation) that transport approximately 150 freight cars, and according to future estimates, it is thought that seven trains catering up to 204 cars will be necessary by the year 2006.

The unit freight trains are designed for direct traffic between freight stations without passing by the sorting yard, as a rule, and so a track layout allowing direct access to freight stations is desirable.

(3) Relationship with the increase in Mae Nam's arrival/departure tracks

When Bang Sue Yard is improved to a flat yard, it will be the Mae Nam's arrival/departure tracks (DT5, DT1) that can be converted most easily to arrival/departure tracks for the Northern and Southern Lines.

However, the F/S survey indicates that it would be difficult to install the inbound and outbound main tracks between the freight station and the arrival tracks.

However, if there are no arrival/departure tracks for the Northern and Southern Lines besides the sorting tracks, the yard will scarcely be compatible with the special relay traffic, etc. It is thus desirable to improve the departure tracks to arrival/departure tracks.

Appendix 7.4.3 Bang Sue Yard Concept

1. Outline

The improvements in the Bang Sue Yard with its handling capacity of 2500 cars/day, consist of reducing it into a yard size that can efficiently handle 900 cars/day.

It is thought that the number of freight cars relayed through the yard will not increase as time goes by, because of the progress in the station-to-station direct transportation system. Because of this, the 900 freight cars handling at the Bang Sue yard are thought to be the maximum, and so a comparative investigation was done to determine the best yard layout to cope with this number.

In this case, the number of freight car and the number of train arrivals and departurs at this yard should use the daily averages for the year 2006.

2. Preconditions for the Bang Sue Yard Improvement Plan

(1) Freight flow table and number of arrival/departure trains by direction for the yard facilities. (See Table 1 and Table 2.)

Table 1 Freight Flow Table by Direction for the Bang Sue Yard

(Daily Average for 2006)

Arrivals / Departures	Northern Line	Northeastern Line	Southern Line	Eastern Line	Mae Nam Line	Terminating at Bang Sue	Car Inspected	Total
Northern Line			48	42	24	[109] 7		[109] 121
Northeastern Line			36	72	5	[95] 23		[95] 136
Southern Line	35	73		42	28	18	20	216
Eastern Line	62	28	69	5	6	[38] 10		[38] 180
Mae Nam Line	10		25	3		18	15	71
Originating from Bang Sue	[109] 10	[95] 10	37	[38] 19	10		10	[242] 86
Car Inspected	20	5				10		35
Total	[109] 137	[95] 116	215	[38] 183	73	[242] 86	35	[484] 845

(Figures in parentheses indicate special commodity cars, and are separate from the figures directly below them.)

Table 2 Number of Freight Trains by Direction for the Bang Sue Yard

(Daily Average for 2006)

Line	Arrivals	Departures	Total
Northern Line	15 [7]	15 [7]	30 [14]
Southern Line	8	8	16
Eastern Line	6 [1]	6 [1]	12 [2]
Mae Nam	6	6	12
Total	35	35	70 [16]

(Figures in parentheses indicate special commodity cars, and are included in the figures directly to their left.)

(2) Number of shunting locomotives

The number of freight cars to be handled by the yard in the future was estimated at approximately 900 cars; therefore, it is necessary to have two or more shunting locomotives within the yard at the same time.

Actually a total of three or more locomotives will be required for simultaneous shunting at Bang Sue station because one locomotive will be necessary for the freight station.

(3) Other facilities

A total of 17 sorting tracks are necessary for sorting by direction and surplus sorting tracks are to be linked to draw-out tracks.

3. Investigation into Track Layout for the Freight Station

The existing facilities at the passenger station, freight station, and engine shed could be used to the greatest extent possible at Bang Sue station. However, the freight station has a close relationship with the track layout at the yard, so an investigation was first performed for the track layout at the freight station.

(1) Entry and exit of general freight cars into or from the freight station

The majority of the general freight cars arrive on the arrival tracks, are decomposed at the hump, and drawn out to the Mae Nam's draw-out track Z_2 to enter the transfer tracks. These cars are then moved to the freight draw-out tracks, sorted for loading/unloading, and placed on the loading/unloading tracks. (Refer to Fig. 1.)

Freight cars sent out from the freight station are moved to the arrival tracks, using the shunting locomotive of the freight station. They are then decomposed by the hump shunting locomotive, and made-up by the draw-out by formation track Z_1, and then placed on the departure track.

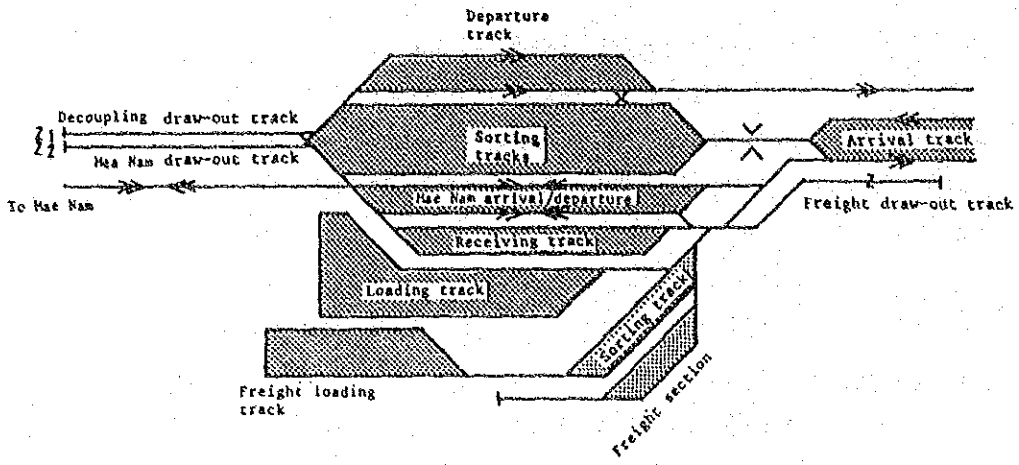


Fig. 1 Track Layout in Bang Sue Freight Station

(2) Handling of container trains and unit cement trains

It is more advantageous to avoid as much as possible the relay work at the yard for the special unit train and directly link them to the departure and arrival stations.

Freight carried directly to the Bang Sue freight station is marine containers and cement. In the future, through trains are planned for the marine containers. However these marine containers will be handled separately from other freights. So container loading/unloading facilities should be constructed separately.

There are presently six special cement trains coming to Bang Sue station from the Northern Line. The two tank-car trains of these trains are directly moved to the unloading tracks by the freight station shunter. The four roofed-car trains are moved to the Mae Nam's arrival/departure tracks by the shunter of these tracks and shunted onto the transfer tracks. Cement cars for other stations are then removed, and most of the remaining cars put on the loading/unloading tracks by the shunter of the freight station, through the draw-out track. Empty tank and roofed cars to be returned are sent out from the loading tracks to the Mae Nam's arrival/departure tracks and then to the departure tracks where they are made-up into train formations.

In this way, the freight cars special cement trains are transfered between some shunters at the yard operation, but if possible, it is desirable that the track layout be improved so that this be done with only the shunters of the freight station, in order to place and remove them onto and from the freight station.

In addition to this, the freight cars by special cement freight trains constitute two-thirds of the number of freight cars at Bang Sue station at present, and in the future, the number is expected to increase to three-fourths (Table 1). Therefore, the track layout should be such that the special cement trains can be directly placed onto and taken off of the tracks at the freight station.

(3) Track layout for the freight station

There are two ways of improving the track layout so that the special cement trains can have their shunting performed by the shunters at the freight station. The first is a plan where the current Mae Nam arrival and departure tracks are improved, and the other is a plan to construct a track for both departure/arrival and shunting on the side of the draw-out track.

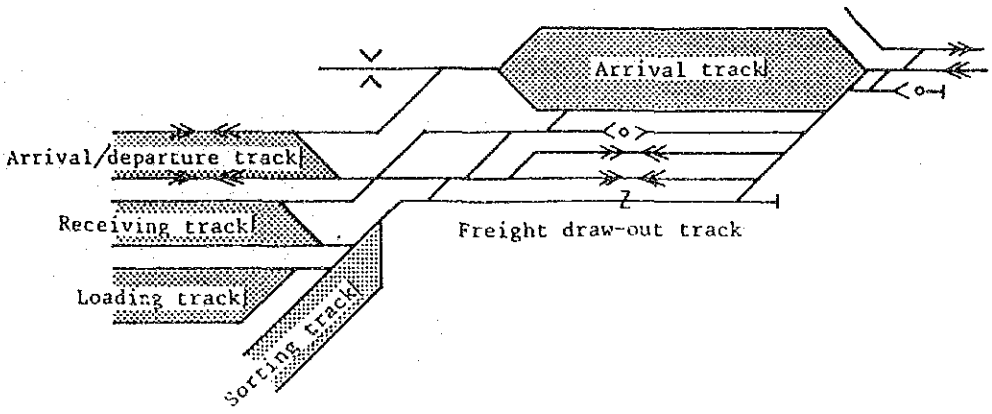


Fig.2 New Construction of Arrival/Departure Track at the Side of the Freight Draw-out Track

The former is for the most general type of track layout, but the placing and draw-out of freight cars at the freight station requires that the cars are turned back once on the freight draw-out tracks. At present, there are many cases where dual-purpose arrival/departure and shunting tracks are placed at the neck of the large

large freight stations like the latter (Mae Nam, Shiodome, Sasajima, Tokyo Freight Terminal). Under the previous improvement plan for the Mae Nam arrival/departure tracks, it is feared that special cement trains will enter the central part of the yard, causing conflict with car-transfer work between the yard and freight station. Moreover, if a policy for yard improvement is not established, the possibility of unnecessary work and rising construction costs occurring becomes very high. It is planned, therefore, to construct tracks for both arrival/departure and shunting on the side of the draw-out track in order to save on construction costs and prevent unnecessary work.

Reference: The balance of construction expenses - approx. 15 million bahts

4. Comparison of Freight Yard Improvement Layouts

(1) Comparison of draft layouts

As can be seen from the rough track layout of the Bang Sue yard (Fig. 3), the yard is enclosed between the main lines. It is a hump yard with a handling performance of 2500 cars.

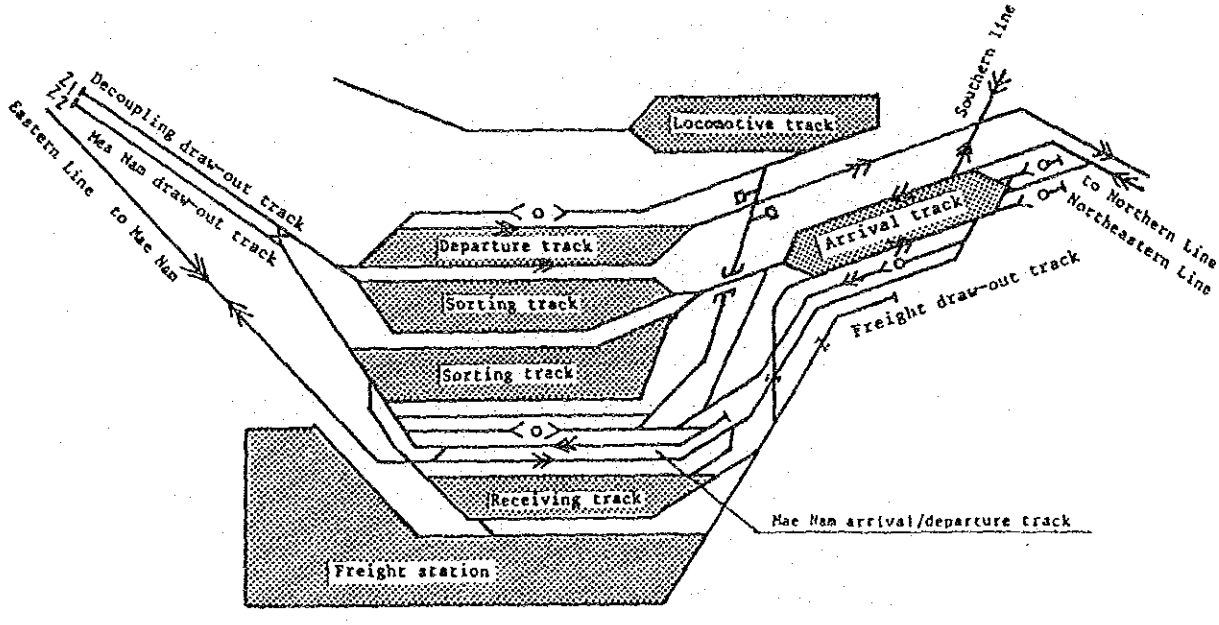


Fig. 3 Track Layout in Bang Sue Yard

When this yard operates, trains on the Northern and Southern Lines can come straight into the arrival tracks. At that time, since there is only one hump, sorting by direction cannot occur the transfer of cars. In addition, this is considered the ideal layout since the train make-up work for the Southern and Northern Lines does not conflict at all with that for the Mae Nam and Eastern Lines.

However, the layout of this yard is basically for handling originating and terminating trains.

Moreover, the number of freight cars to be handled by the yard is estimated to be 900 or less in the future, so the layout of this yard must be thoroughly investigated. Therefore, on the basis of the yard's current track layout, layouts for which implementation is possible were drawn and shunting locomotives work range determined, and the number of freight cars that can be handled by the shunters were calculated. With the above results, the construction expenses and major problems are compared regarding the plans for feasible freight layouts. Two or three draft plans were then selected and further comparisons then made.

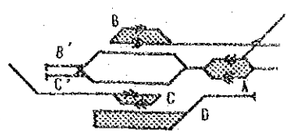
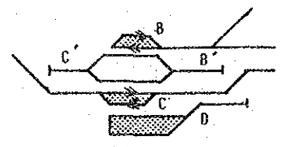
(2) Layout comparison on the basis of the current plane form

Part of the plane form of the existing Bang Sue yard was arranged, and the role of the shunters used to calculate the number of freight cars that they handled. The results are shown in Table 3.

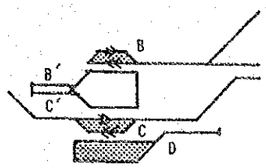
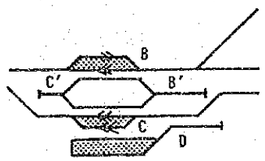
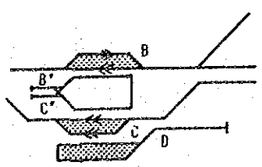
Furthermore, each of the draft improvement plans shown in the table has been given a number to facilitate handling in the chapters thereafter and have no particular significance.

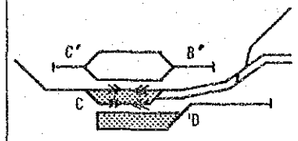
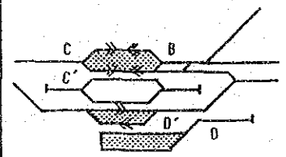
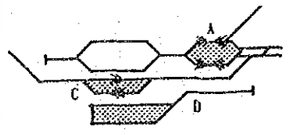
Table 3 Investigation into the Number of Freight Cars that can be Handled by Shunting Locomotives in Each Draft Improvement Plan for the Bang Sue Yard

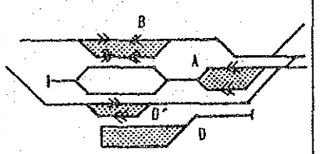
Unit: car

Draft \ Direction	Shunting locomotive	Cement trains		Northern Line, Northeastern Line		Southern Line		Eastern Line, Mae Nam Line		Station		Car inspected		Total	Main work of shunting locomotives
		Receiving 204	Sending 204	Uncoupling 257	Coupling 253	Uncoupling 216	Coupling 215	Uncoupling 251	Coupling 256	Receiving 86	Sending 86	Receiving 35	Sending 35		
2-3 Current state 	A			257		216		194			86		35	788	A. Uncoupling of trains arriving on the Northern and Southern Lines and of cars originating or terminating of Bang Sue
	B		[204/2]		253		215							[570] 468	B. Coupling of cement trains and trains departing on the Northern and Southern Lines
	C	[204]	[204/2]					251	256	86/2		35/2		[874] 568	C. Uncoupling and coupling of trains arriving and departing on the Mae Nam Line, uncoupling of cement trains and receiving of terminating cars
	D	204	204							86	86	35	35	650 S [2,882] 2,474	D. Receiving and sending of originating or terminating cars (including cement trains)
1-3' Discarding of arrival tracks (including those for cement trains) 	B		[204/2]		253	216	215							786	B. Coupling of trains leaving on the Northern Line uncoupling and coupling of the trains arriving and leaving on the Southern Line, coupling of cement trains
	C	[204]		257				251	256	86/2	86	35/2	35	[1,160]	C. Uncoupling of trains arriving on the Northern Line, uncoupling and coupling of the trains arriving and departing on the Mae Nam Lines, uncoupling of special cement trains and cars, cuncoupling of originating cars, receiving of terminating cars
	D	204	204							86	86	35	35 S [2,596]	650	D. Receiving and sending of originating or terminating cars
1-3 Discarding of arrival tracks (separating cement trains) Same as 1-3'	B				253	216	215							684	B. Coupling of trains leaving on the Northern Line, uncoupling and coupling of trains arriving and leaving on the Southern Line
	C			257				251	256	86/2	86	35/2	35	946	C. Uncoupling of trains arriving on the Northern Line, uncoupling and coupling of trains arriving and departing on the Mae Nam Lines, uncoupling of originating cars
	D	204	204							86	86	35	35 S 2,280	650	D. Uncoupling and coupling of cement trains, receiving and sending of originating or terminating cars

Note: Figures in boxes are for the case where special cement trains are handled, which is one-half of the number of cars for simple relay work.

Draft \ Direction	Shunting locomotive	Cement trains		Northern Line, Northeastern Line		Southern Line		Eastern Line, Mae Nam Line		Station		Carriage inspected		Total	Main work of shunting locomotives
		Receiving 204	Sending 204	Uncoupling 257	Coupling 253	Uncoupling 216	Coupling 215	Uncoupling 251	Coupling 256	Receiving 86	Sending 86	Receiving 35	Sending 35		
1-3" Discarding of arrival tracks (separating cement trains from shunting work, single-side draw-out) 	B			84	253	216	215	194			57		25	1,044	B. Coupling of trains leaving on the Northern Line, uncoupling and coupling of trains arriving and departing on the Southern Line
	C			257		108		251	256	86/2	86	35/2	35	1,054	C. Uncoupling of trains arriving on the Northern Line, uncoupling and coupling of trains arriving and departing on Mae Nam Lines, uncoupling of originating cars
	D	204	204							86	86	35	35	650	D. Uncoupling and coupling of cement trains, receiving and sending of originating or terminating cars
1-4 Enclosed type (separating cement trains from shunting work) 	B				253	216	215	251						935	B. Coupling of trains leaving on the Northern Line, uncoupling of trains arriving on the Mae Nam Lines, uncoupling and coupling of trains arriving and departing on the Southern Line
	C			257					256	86/2	86	35/2	35	695	C. Uncoupling of trains arriving on the Northern Line, coupling of trains departing on the Mae Nam Lines, uncoupling of originating cars
	D	204	204							86	86	35	35 S	650 2,280	D. Uncoupling and coupling of cement trains, receiving and sending of originating or terminating cars
1-4" Enclosed type (separating cement trains from shunting work single-side draw-out) 	B			84	253	216	215	251		57		25		1,101	B. Coupling of trains leaving on the Northern Line, uncoupling of trains arriving on the Mae Nam Lines, uncoupling and coupling of trains arriving and departing on the Southern Line
	C			257		108		43	256	86/2	86	35/2	35	860	C. Uncoupling of trains arriving on the Northern Line, coupling of trains departing on the Mae Nam Lines, uncoupling of originating cars
	D	204	204							86	86	35	35 S	650 2,611	D. Uncoupling and coupling of cement trains, receiving and sending of originating or terminating cars

Draft \ Direction	Shunting locomotive	Cement trains		Northern Line, Northeastern Line		Southern Line		Eastern Line, Mae Nam Line		Station		Inspected Carriages		Total	Main work of shunting locomotives
		Receiving 204	Sending 204	Uncoupling 257	Coupling 253	Uncoupling 216	Coupling 215	Uncoupling 251	Coupling 256	Receiving 86	Sending 86	Receiving 35	Sending 35		
1-2 Discarding of arrival and departure tracks 	B				253		215	251						719	B. Coupling of trains departing on the Northern and Southern Lines, uncoupling of trains arriving on the Mae Nam Lines
	C	204/2	204/2	257		216			256	86/2	86	35/2	35	1,110 910	C. Uncoupling of trains arriving on the Northern and Southern Lines, coupling of trains departing on the Mae Nam Lines, uncoupling of originating or terminating cars
	D	204	204							86	86	35	35 S	650 2,506 2,280	D. Receiving and sending of originating or terminating cars
1-1 Providing extra departure tracks 	B				253		215	251		86/2	86	35/2	35	901	B. Coupling of trains departing on the Northern and Southern Lines, uncoupling of trains arriving on the Mae Nam Lins, uncoupling of originating cars
	C			257		216			256					729	C. Uncoupling of trains arriving on the Northern and Southern Lines, coupling of trains departing on the Mae Nam Lines
	D	204	204							86	86	35	35 S	650 2,280	D. Handling of cement trains, receiving and sending of originating or terminating cars
2-2 Providing extra arrival tracks *(mixed coupling and* uncoupling) 	A			257	253	216	215							941	A. Uncoupling and coupling of trains arriving and departing on the Northern and Southern Lines.
	C							251	256	86/2	86	35/2	35	689	C. Uncoupling and coupling of trains arriving and departing on the Mae Nam Lines, uncoupling of originating cars
	D	204	204							86	86	35	35 S	650 2,280	D. Uncoupling of cement trains, receiving and sending of originating or terminating cars

Draft \ Direction	Shunting locomotive	Cement trains		Northern Line, Northeastern Line		Southern Line		Eastern Line, Mae Nam Line		Station		Inspected carriages		Total	Main work of shunting locomotives
		Receiving 204	Sending 204	Uncoupling 257	Coupling 253	Uncoupling 216	Coupling 215	Uncoupling 251	Coupling 256	Receiving 86	Sending 86	Receiving 35	Sending 35		
2-2(b) Providing extra arrival tracks (separated coupling and uncoupling)	A			257		216		251			86		35	845	A. Uncoupling of trains arriving on the Northern, Southern, the Mae Nam Lines, and originating cars
Same as 2-2 (a)	C				253		215		256	86/2		35/2		785	C. Coupling of trains departing on the Northern, Southern, the Mae Nam Lines
	D	204	204							86	86	35	35	650	D. Uncoupling of cement trains and receiving and sending of originating or terminating cars
													S	2,280	
2-1 Providing extra arrival tracks (using departure tracks) 	A			257		216		251			86		35	845	A. Uncoupling of trains arriving on the Northern, Southern, the Mae Nam Lines, and originating cars
	B				253		215		256	86/2		35/2		785	B. Coupling of train departing on the Northern, Southern, the Mae Nam Lines.
	D	204	204							86	86		35	650	D. Uncoupling of cement trains and receiving and sending of originating or terminating cars
													S	2,280	

The following can be understood from Table 3.

As can be seen from Plan 2-3 (the current state), when there are 4 shunters, the number of cars handled is less than 1000 including the cars of special cement trains. This is within the work capacity. However, in the other draft improvement plans, bringing the special cement freight trains into the yard can not be handled by the shunters and results in an unviable plan. Thus, the freight of the special cement trains must be separated from the yard.

In addition, consideration of sorting tracks by direction indicates that all the plans are viable in cases where one sorting track is commonly used from both sides in the same way. However, in a draft with two-draw-out tracks on one side, in which sorting tracks cannot be used commonly in the same way, it is not feasible due to car transfering work.

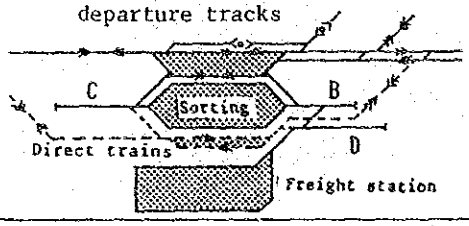
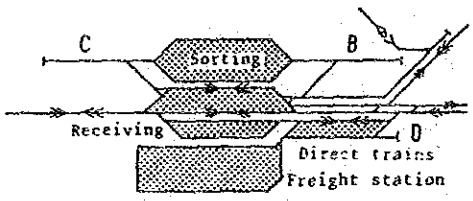
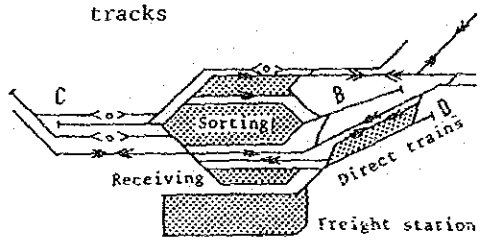
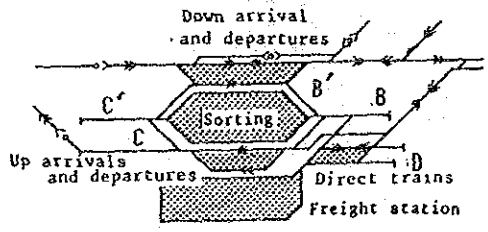
In view of these results, Draft Improvement Plans
1-3', 1-3" and 1-4" have been eliminated.

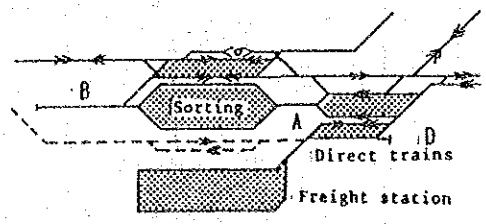
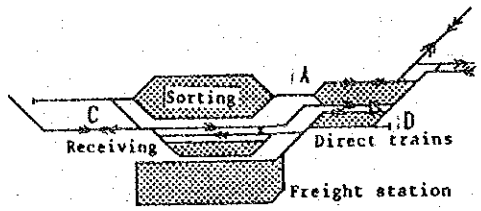
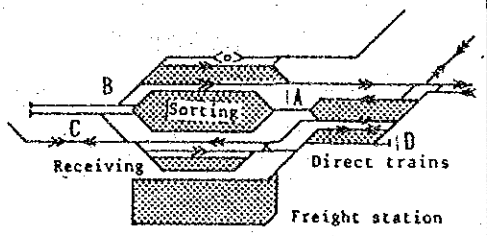
(3) Organization of the drafts for which design is possible, and the selection of a draft plan

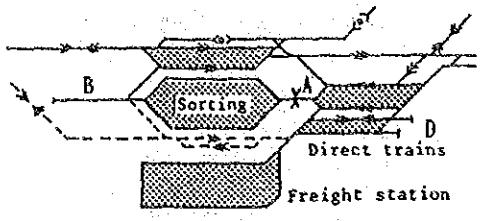
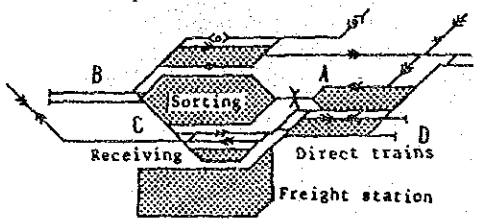
Each of the draft improvement plans in Table 3 were organized and summarized as shown in Table 4.

A comparison of the various draft improvement plans in Table 4 was performed to select two or three plans that have few defects and low construction costs.

Table 4 Comparison of Draft Improvement Plans for Bang Sue Yard

Item / Draft	Total number of shunting locomotives	Number of freight cars handled by shunting locomotives	Competition between arriving and departing trains	Ease in entering or leaving the depot	Replacement of locomotives	Giving and receiving of cars to or from freight station	Net consruction cost
1. Flat yard, and parallel type with parallel arrival/ departure and sorting tracks							Million Bahts
1-1 Draft to strengthen departure tracks 	3	B - 901 C - 729 D - 650 2,280	A little	Easy	Easy	Easy	173
1-2 Draft to strengthen arrival/ departure tracks 	3	B - 719 C - 911 D - 650 2,280	A little	A little diffi-cult	Diffi-cult	A little diffi-cult	194
1-3 Draft to use existing arrival depaturetracks and departure tracks 	3	B - 694 C - 946 D - 650 2,280	None	Easy	Diffi-cult	A little diffi-cult	210
1-4 Enclosed type 	3	B - 935 C - 695 D - 650 2,280	None	A little diffi-cult	Easy	A little diffi-cult	188

Item / Draft	Total number of shunting locomotives	Number of freight cars handled by shunting locomotives	Competition between arriving and departing trains	Ease in entering or leaving the depot	Replacement of locomotives	Giving and receiving of cars to or from freight sta-	Net construction cost
2. Flat yard, series type arrival and sorting tracks							Million Bahts
2-1 Draft using existing arrival and departure tracks 	3 Trains	A - 845 B - 785 D - 650 2,280	None	A little difficult	Easy	Easy	203
2-2 Draft using existing arrival and arrival/departure tracks 	3	A - 941 C - 689 D - 650 2,280	Yes	A little difficult	Difficult	Difficult	189
2-3 Current layout 	3	A - 788 B - 468 C - 568 D - 650 2,474	None	A little difficult	Difficult	A little difficult	156

Item / Draft	Total number of shunting locomotives	Number of freight cars handled by shunting locomotives	Competion between arriving and departing trains	Ease in entering or leaving the depot	Replacement of locomotives	Giving and receiving of cars to or from freight station	Net construction cost
3. Hump yard 3-1 Draft using existing arrival and departure tracks 	3	A - 845 B - 785 C - 659 2,280	None	Easy	Easy	Easy	94
3-3 F/S improvement draft 	4	A - 788 B - 468 C - 568 D - 650 2,474	None	Easy	Difficult	Easy	Million Bahts 42

1) Type with flat yard, parallel type with arrival/departure and sorting tracks (1-1, 1-2, 1-3, 1-4)

There is a little fear that Draft 1-1, for strengthening departure tracks, will result in concurrence between the arrival and departure trains; otherwise, there are no particular problems. Construction costs are also fairly low, so it is a promising draft.

Similar to 1-1 is Draft 1-4, an enclosed type. This plan has low construction costs because the engine tracks for terminating Northern Line trains that arrive on the up arrival/departure tracks are also used as the main tracks for the Mae Nam and Eastern Lines on the Bangkok side. This is planned as a relief measure when there is much concurrence between trains in both directions in Draft 1-1.

Draft 1-2, which provides more arrival/departure tracks in the existing layout, has arrival/departure tracks placed between the freight station and the sorting tracks of the yard. This has more difficulties than Draft 1-1 in the transfer of cars with an engine track and freight station, and also has high construction costs and cannot be considered viable. Draft 1-3, which uses the existing arrival/departure tracks and departure tracks, will improve the concurrence between arrival/departure trains and the locomotives entering or leaving the depot and are improved in Draft 1-2. But, in view of the very high construction costs as compared to the degree of improvement, the plan is not viable.

2) Flat yard, series type with arrival and sorting tracks

In Draft 2-1, regarding the existing arrival tracks and departure tracks, there are some problems with the locomotive of the arrival trains entering or leaving the depot, but there are no other defective factors. Nevertheless, the extremely high cost prevents it from being a viable plan.

Draft 2-2, for the existing arrival track and arrival/departure tracks, has coupling work as well as uncoupling work performed on the arrival tracks for trains from the Southern and Northern Lines, so there is concurrence with the arrival and departure trains, and between engine operation and shunting work, all being duplicated. Accordingly, although it is an inexpensive plan, it is not viable.

Draft 2-3, the present layout plan, has comparatively inexpensive construction costs, but the number of shunter is not reduced and the yard does not become any easier to use. This proposal does not satisfy the objectives of improvement and is therefore not viable.

3) Hump yard(3-1, 3-3)

Types 3-1 and 3-3 are the same as 2-1 and 2-2, attached the hump in Table 3.

The yard plan for the series type with arrival tracks and sorting tracks appears to be the most advantageous layout for the hump yard uncoupling mainly terminating trains. In general, each of the draft plans 2 for the flat yard can be used in the hump yard, but Draft 2-2, requires composing on the arrival tracks, so it is not applicable to the hump yard.

Draft 3-1, using the arrival tracks and departure tracks, has few defective factors and is an inexpensive plan that is desirable along with the present layout plan.

4) Conclusion

Out of the results of the above investigation, it was decided to conduct a thorough investigation into the following plans.

Flat yard: 1-1 Providing extra departure tracks
1-4 Enclosed track plan

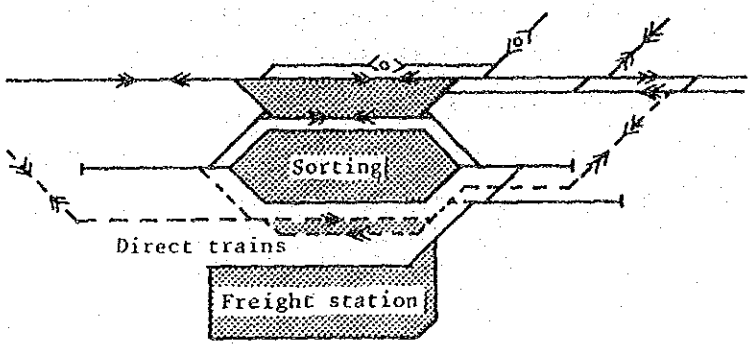
Hump yard: 3-1 Use of existing arrival tracks and departure tracks
3-3 F/S improvement plan

5. Basic concept for improvement of the freight yard

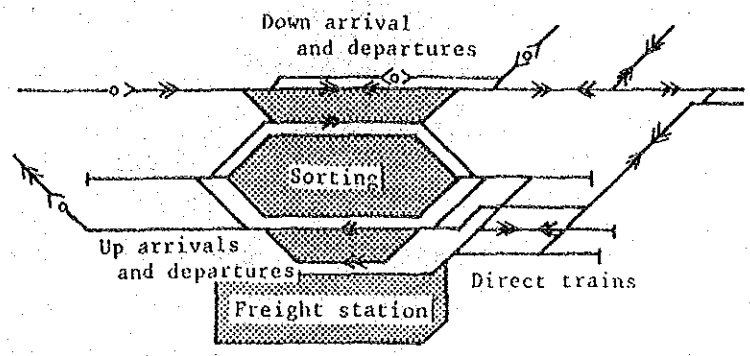
(1) Advantages of each yard

(a) Flat yard

1-1 Draft to strengthen departure tracks

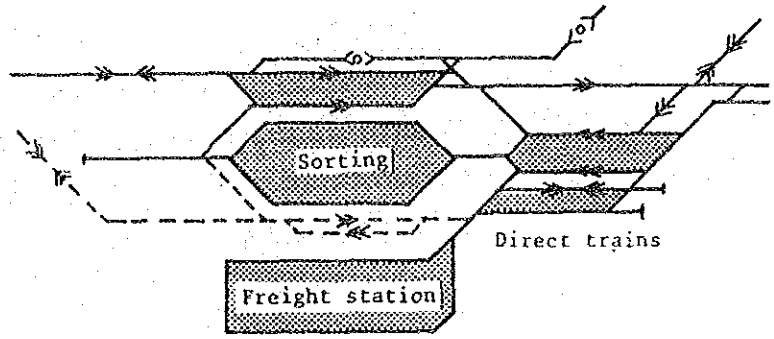


1-4 Enclosed type



(b) Hump yard

3-1 Draft to use existing arrival and departure tracks



3-3 F/S improvement layout

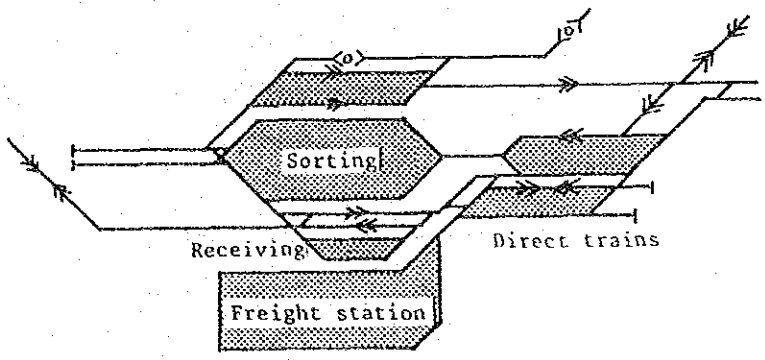


Fig. 4 Draft Improvement Plan for Bang Sue Yard

Fig. 4 shows the plans improving the Bang Sue yard, selected primarily in view of the number of cars to be handled by the shunter and construction costs.

As can be seen from the diagram, in all plans other than 3-3, F/S improvement plan, the existing departure tracks and the main line to Bangkok are linked, with the layout arranged so that trains arriving from Mae Nam can arrive on the current departure tracks. This has the following advantages.

1) The run-round operation of the locomotives for terminating trains is facilitated.

2) Changing of locomotives for trains passing through the station from Mae Nam is also facilitated. (The locomotives are generally changed for down trains.)

3) It is easy to perform special relay work for freight cars.

4) Concurrence between arrival trains and departure trains may be as large as that of Draft 1-1, but this will not present any major problems.

5) There are some cases of car transfer with the freight station in Draft 1-4, but this will not present any major problems.

(2) Relationship between the construction costs and the reduction of the number of shunting locomotives and personnel

As was indicated in the previous section, there were no great differences brought out for the functions of the selected plans, so the final selection was made in view of the relationship between the construction costs, and reductions in the number of shunter and personnel as show in Table 5.

Table 5 Relationship between Construction Costs and Reduction of the Number of Shunting Locomotives and Personnel

	Increase in construction expenses	Reduction in number of shunting locomotives	Reduction in personnel		Total amount saved annually	Notes
			Kinds of jobs	Number of persons		
Conversion of draft 3-3 to draft 3-1	Million bahts 94 - 42 = 52	1	Shunting personnel	3 Persons x 5shifts = 15 persons	Million bahts/ year	* Shunting locomotives (10 years) 11 million bahts/locomotive
			Driver	2 Persons x 5shifts = 10 persons		* Salaries to employees 65,850 bahts/ year
			Car inspector	10 persons		* Expenses including management and welfare double the above amount
			Total	35	5.6	
Plan 3-1 changed to Plan 1-1	173 - 94 = 79	--	Car retarder personnel	3		* Personnel not concern- Staff - 4 persons Chief of Shunter - 7 persons Total 11 persons
			Car stopper	24		
			Hump personnel	3		
			Shunting Level Personnel	12		
			Sub-total	30		
			Retarder maintenance personnel (mechanic)	3		* Retarder maintenance cost 0.6 million B/year
			Total	33	4.9	

As a result, if F/S Inprovement Plan 3-3 is used with the hump and converted to Draft 3-1, which uses the existing arrival tracks and departure tracks, it will result in the reduction of one shunter and related personnel(Refer to Table 5).

However, if Draft 3-1 is pursued further and converted into a flat yard plan, the result will be disadvantageous.(It is assumed that construction expenses will be recouped in 10 years.)

However, Plans 3-1 changed to plan 1-1 are not much different in the cost, and depending on the SRT policy or change in the circumstances, Plan 1-1 may become advantageous over Plan 3-1.

(3) Conclusions

From the foregoing, Plan 3-1 is recommended as a comprehensive plan for the Bang Sue yard to pursue with the hump yard used in its present condition as it is, provided efforts are made to collect the arrival and departure tracks at one place and reduce the required personnel to a minimum.

Furthermore, minute examination is required when the work is actually made because of the small difference in the ratio of the increased construction cost to the saved amount between Plans 3-1 and 1-1.

However, Draft 3-1 requires large construction costs of about 18 million bahts for a bridge to be built on the Bangkok side.

In this regard, further savings can be effected by taking such measures as saving on construction costs by utilizing the existing bridge until the start of the operation of marine container trains.

Appendix 7.4.4 Crossing of the Eastern Line's Freight Trains Over the Northern Line's Inbound Main Track between Chitralada and Bang Sue

The inbound and outbound passenger trains on the Northern Line number 48 a day, and the Eastern Line inbound freight trains number 20 a day (Fig. 1). In entering the Northern Line's outbound track from the Eastern Line at Chitralada, freight trains must cross the Northern Line's inbound tracks, which has many trains.

Now, assuming that a freight train crosses or merges into another track and that the passenger trains in the same direction are operated at a train interval of 12 minutes or more (described later), the time precluding crossing or merging according to the current diagram is calculated as follows.

(1) Time precluding crossing over the Northern Line's inbound main track
5 minutes x 8 (intervals) + 9 minutes x 14 (intervals) = 166 minutes/day
Percentage of one day's operating time (effective time zone 20 hours) - About 14%

(2) Time precluding running into the Northern Line's outbound main track
6 minutes x 8 (intervals) + 9 minutes x 11 (intervals) = 139 minutes/day
Percentage of one day's operating time - About 12%

(3) Time precluding both the crossing of the Northern Line's inbound main track and merging into the Northern Line's outbound main track
5 minutes x 32 (intervals) + 9 minutes x 30 (intervals) = 550 minutes/day
Percentage of one day's operating time - About 46%

Thus, the time allowed for trains from the Eastern Line to cross the Northern Line's inbound main track and merge into the Northern Line's outbound main track is only about 54% of a day's operation. However, if train frequency increases in the future, merging from the Eastern Line into the Northern Line's outbound main track will become more difficult.

A passenger train interval of 12 minutes or more is calculated as below.

Minimum headway for a passenger train and a freight train	5 minutes
Allowance for crossing at ground level	1 minute
Total	6 minutes

Accordingly, 12 minutes (6 x 2 = 12) is necessary for passenger train intervals.

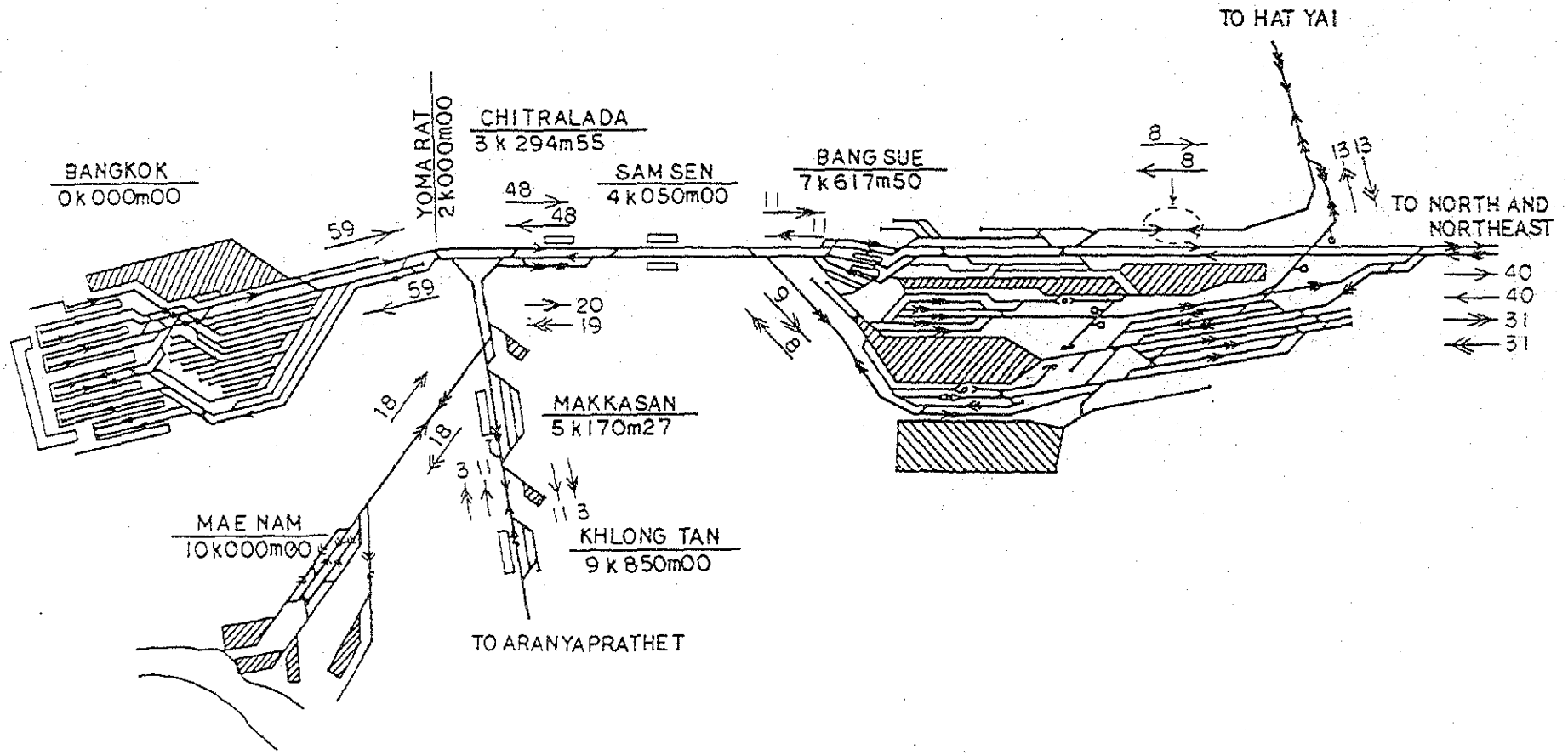


Fig. 1 Train Frequencies Near Bangkok Metropolis (According to 1986 Diagram)

Appendix 7.4.5 Line Capacity between Bang Sue and Bang Bamru

$$\text{Line capacity } C = \frac{1440}{t + S} \times \alpha$$

$$= \frac{1440}{17 + 2.5} \times 0.6 = 44 \text{ Trains}$$

t: Mean operating time between stations

S: Train handling time

α: Line utilization efficiency

Appendix 7.4.6 Loss Time Due to Speed Limit at Crossing of Northern Line and Southern Line's Freight Track

1. Formulas for Calculating Running Time and Running Distance during Acceleration and Deceleration

$$t = \frac{V_2 - V_1}{\alpha}$$

$$S = \frac{V_2^2 - V_1^2}{7.2\alpha}$$

t: Running time for changing speed from V_1 to V_2 (sec)
S: Running distance for changing speed from V_1 to V_2 (m)
V_1: Initial speed of train (km/h)
V_2: Speed of train after acceleration or deceleration (km/h)
α: Acceleration or deceleration (km/h/sec)

2. Calculation of Loss Time for DRC Trains

Acceleration = 1.5 km/h/sec
Deceleration = 1.75 km/h/sec

(1) Reducing to 30 km/h

1) Distance and time required to reach a speed of 80 km/h after departure from Bang Sue

$$S = \frac{80^2 - 0^2}{7.2 \times 1.5} = 593 \text{ m}$$

$$t = \frac{80 - 0}{1.5} = 53 \text{ m}$$

2) Distance and time required for reducing speed from 80 km/h to 30 km/h

$$S = \frac{30^2 - 80^2}{7.2 \times 1.75} = 437 \text{ m}$$

$$t = \frac{30 - 80}{1.75} = 29 \text{ m}$$

3) Distance and time of running at 80 km/h

S = 1,930 m - 593 m - 437 m = 900 m

$$t = \frac{3,600 \times 0.900}{80} = 41 \text{ sec}$$

4) Distance and time of running at 30 km/h

S = One train composition length = 8 cars x 20 m = 160 m

$$t = \frac{3,600 \times 0.160}{30} = 19 \text{ sec}$$

5) Distance and time required for accelerating from 30 km/h to 80 km/h

$$S = \frac{80^2 - 30^2}{7.2 \times 1.5} = 509 \text{ m}$$

$$t = \frac{80 - 30}{1.5} = 33 \text{ sec}$$

6) Distance and time for running at 80 km/h after starting from Bang Sue, passing the crossing of the freight tracks of the Northern and Southern Lines at 30 km/h and accelerating back to the speed to 80 km/h.

S = 593 + 437 + 900 + 160 + 509 = 2,599

t = 53 + 29 + 41 + 19 + 33 = 175 sec

(2) Passing at 80 km/h

1) Distance and time required to reach a speed of 80 km/h after departure from Bang Sue

$$S = \frac{80^2 - 0^2}{7.2 \times 1.5} = 593 \text{ m}$$

$$t = \frac{80 - 0}{1.5} = 53 \text{ sec}$$

2) Time required to reach a speed of 80 km/h at a point 2,599 m from Bang Sue

$$t = \frac{3,600 \times 2.006}{80} = 143 \text{ sec}$$

(3) Time in the case of reducing speed to 30 km/h versus 80 km/h passing speed

1) Reducing speed to 30 km/h 175 sec
2) Passing at 80 km/h 143 sec
3) Time lost for reducing speed to 30 km/h 32 sec

3. Calculation of Loss Time for PC Trains

Acceleration α = 1.0 km/h/sec
Deceleration α' = 1.75 km/h/sec

(1) Reducing to 30 km/h

1) Distance and time required to reach a speed of 80 km/h after departure from Bang Sue

$$S = \frac{80^2 - 0^2}{7.2 \times 1.0} = 889 \text{ m}$$

$$t = \frac{80 - 0}{1.0} = 80 \text{ sec}$$

2) Distance and time required for reducing speed from 80 km/h to 30 km/h

$$S = \frac{30^2 - 80^2}{7.2 \times 1.25} = 611 \text{ m}$$

$$t = \frac{30 - 80}{1.25} = 40 \text{ sec}$$

3) Distance and time of running at 80 km/h

S = 1,930 - 889 - 611 m = 430 m

$$t = \frac{3{,}600 \times 0.430}{80} = 19 \text{ sec}$$

4) Distance and time of running at 30 km/h

S = One composition length = 19 x 20 m = 380 m

$$t = \frac{3{,}600 \times 0.380}{30} = 46 \text{ sec}$$

5) Distance and time required for accelerating from 30 km/h to 80 km/h

$$S = \frac{80^2 - 30^2}{7.2 \times 1.0} = 764 \text{ m}$$

$$t = \frac{80 - 30}{1.0} = 50 \text{ sec}$$

6) Distance and time for running at 80 km/h after starting from Bang Sue, passing the crossing of the freight tracks of the Northern and Southern Lines at 30 km/h and accelerating back to the speed to 80 km/h.

$S = 889 + 611 + 430 + 380 + 764 = 3,074$ m

$t = 80 + 40 + 19 + 46 + 50 = 235$ sec

(2) Passing at 80 km/h

1) Distance and time required to reach a speed of 80 km/h after departure from Bang Sue

$$S = \frac{80^2 - 0^2}{7.2 \times 1.0} = 889 \text{ m}$$

$$t = \frac{80 - 0}{1.0} = 80 \text{ sec}$$

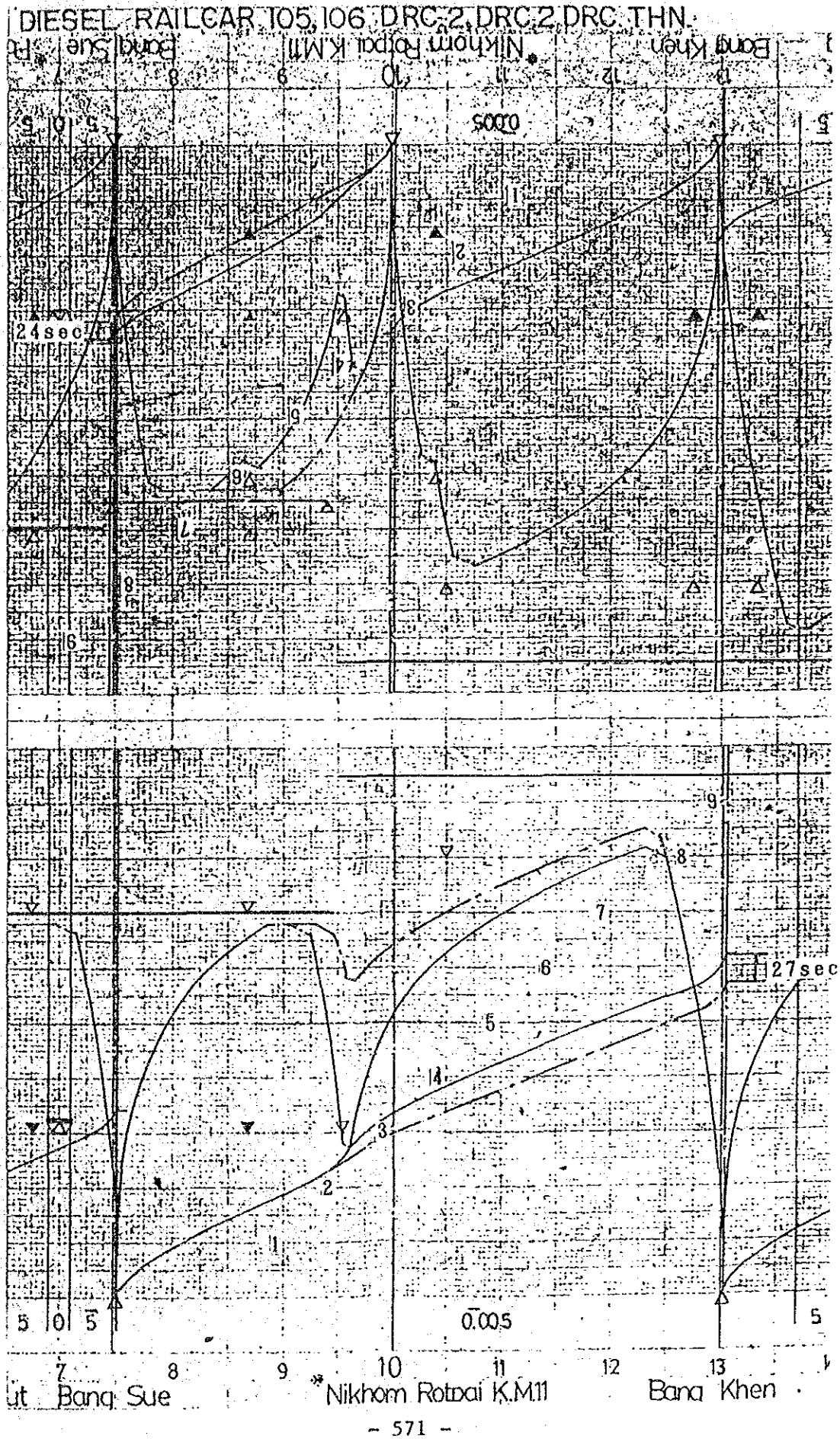
2) Time required to reach a speed of 80 km/h at a point 3,074 m from Bang Sue

$$t = 80 + \frac{3,600 \times 2.185}{80} = 178 \text{ sec}$$

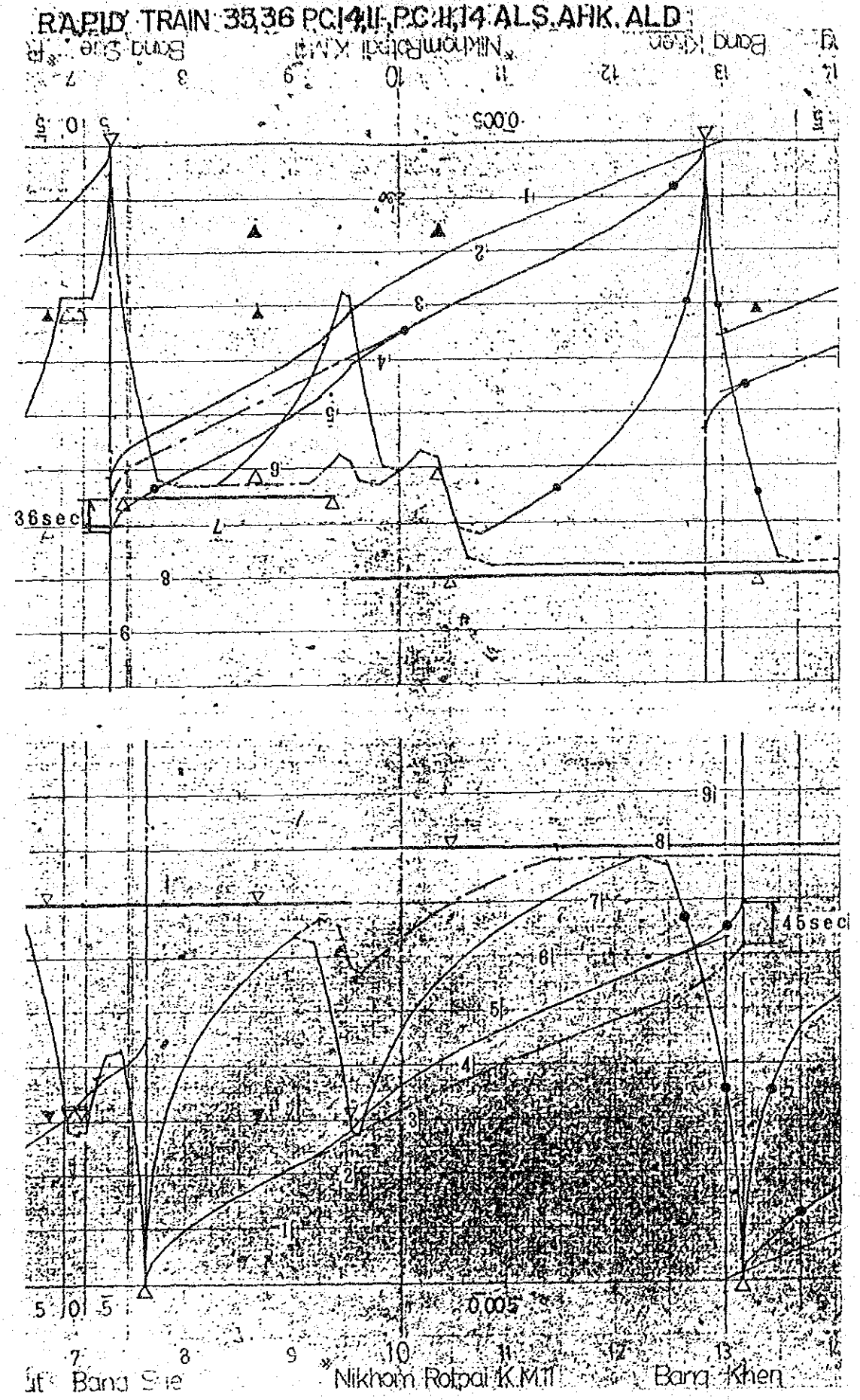
(3) Comparison of time in the case of reducing speed to 30 km/h with that of the 80 km/h passing speed

1) Reducing speed to 30 km/h	235 sec
2) Passing at 80 km/h	178 sec
3) Time lost for reducing speed to 30 km/h	57 sec

4. Loss Time of DRC Trains due to Speed Curves



5. Loss Time of PC Trains due to Speed Curves



(1) The 1st changeover work

1) Track

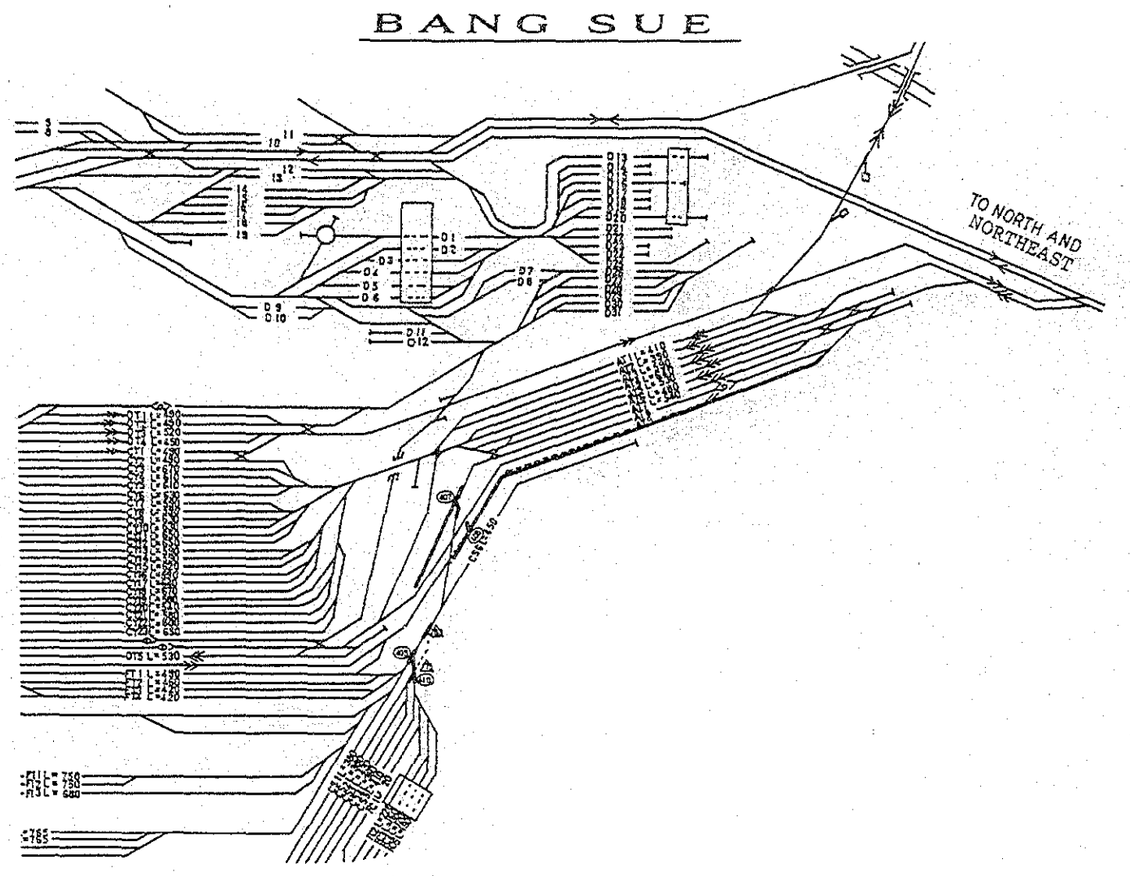


Fig. 1 The 1st Changeover Work Diagram (Track)

1-1 Improvement of freight station entrance

(1) Turnouts 179 and 183 are removed and 409 and 410 introduced.

1-2

Track No. AT9 is no longer removed and is relaid at another location. turnout 408 is provided. Turnout 408 is set up.

1-3 Improvement for gradient modification

(1) Turnout 407 is introduced.

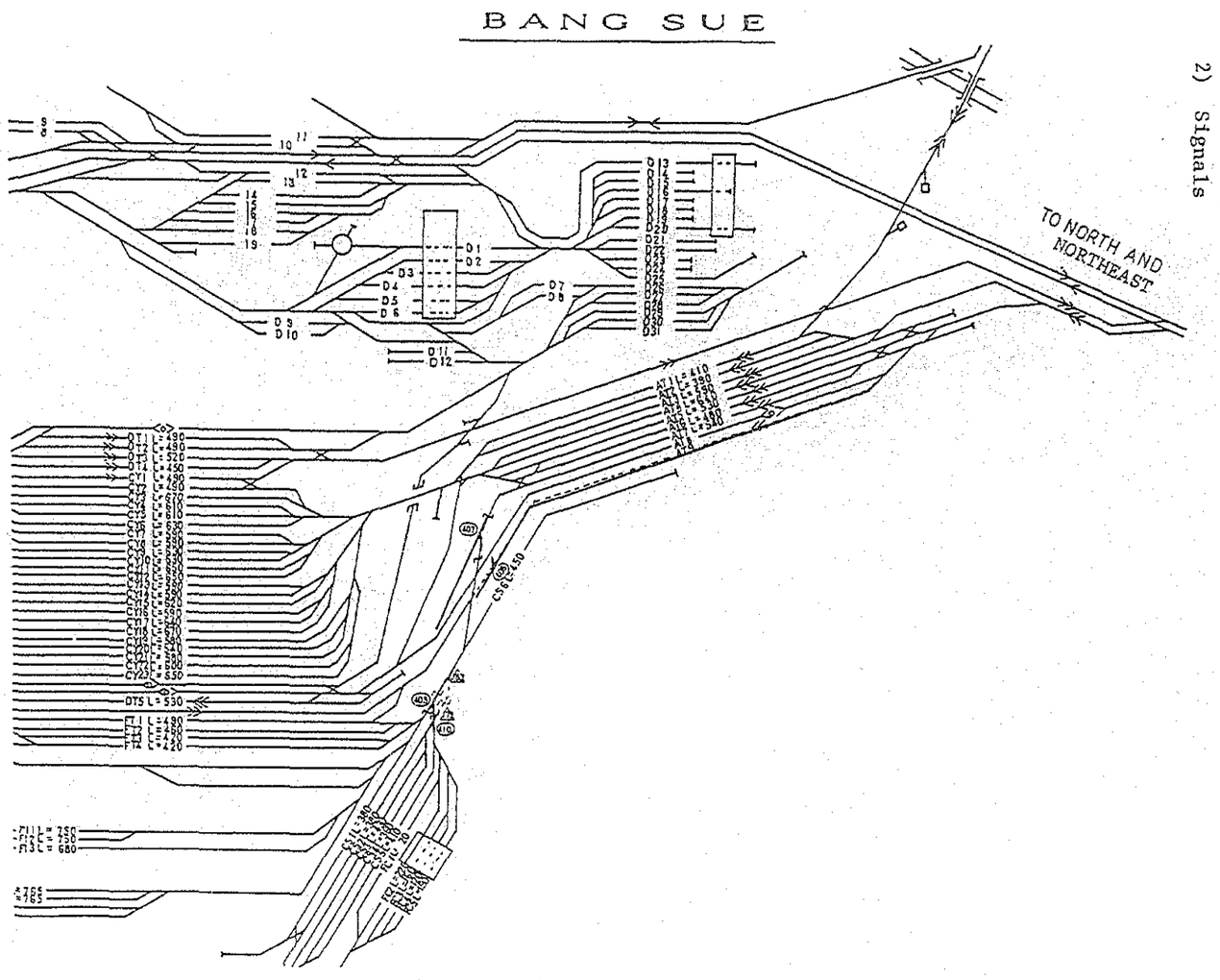


Fig. 2 The 1st Changeover Work Diagram (Signals)

(1) Prior testing

Control panel repairs
Wiring modifications

(2) The electric switch machines of the removed turnouts △179 and △183 are moved to positions (409) and (410).

(3) Turnout (408) is of a key lock

(4) Accompanying the suspension of the use of AT9, a part of the routes for related signal devices are also decommissioned.

(5) An electric switch machine is to be installed for turnout (407).

(6) Turnouts that are removed and introduced are accompanied by the removal, new construction and reconfiguration of the track.

(7) Track testing performed

Track circuit test
Railroad switch conversion test
Signal display test

(2) The 2nd changeover work

1) Track

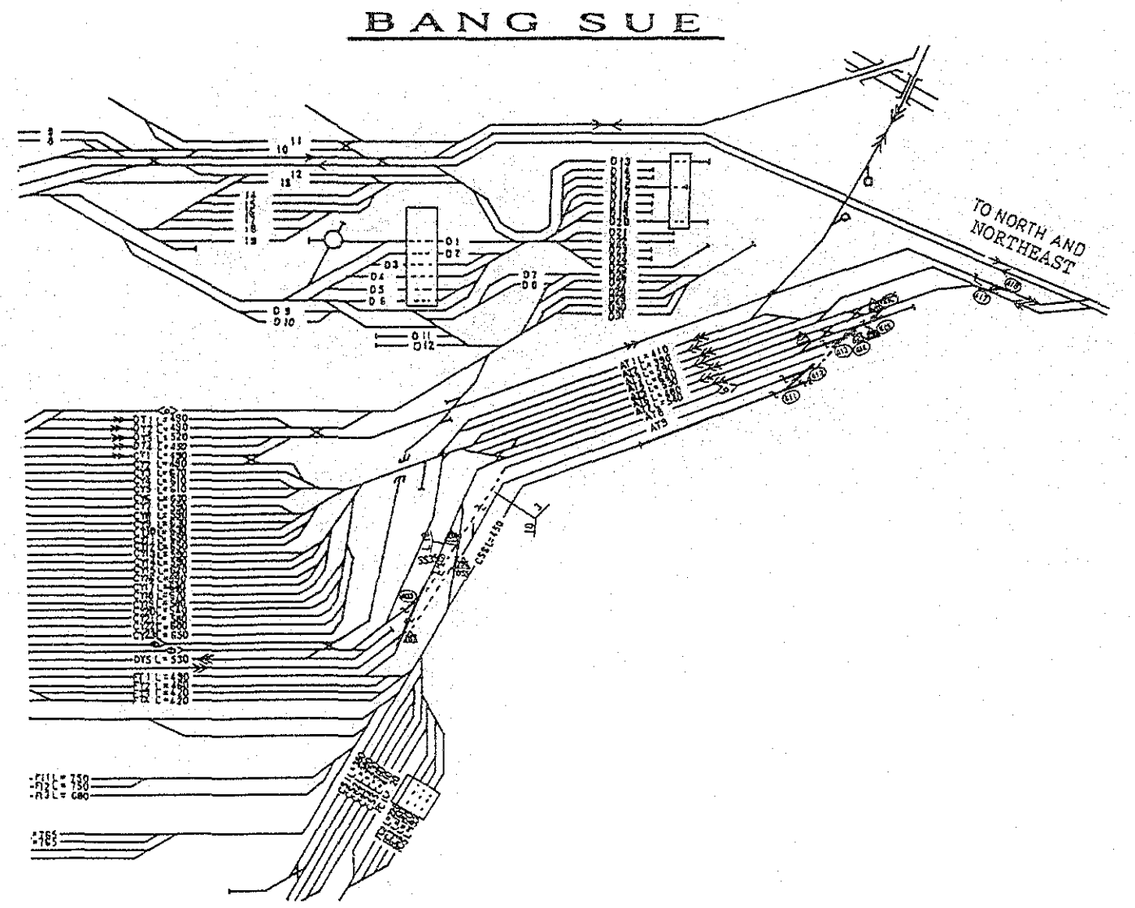


Fig. 3 The 2nd Changeover Work Diagram (Track)

2-1 Gradient modification

(1) Introduction of turnout (403), relocation of △185

(2) Use of track AT8 is discontinued and DSS △196 and △190 removed

(3) Gradient modification is performed

2-2 Improvement of track No. AT9

(1) Removal track CS6 is extended and turnouts (411) and (412) newly constructed

2-3 Improvement of main route

(1) Turnouts (417) and (418) are introduced and both linked

(2) Turnouts △259 and △258 are removed and (415) and (416) introduced and linked

2-4 Route changing for track No. AT7

(1) Turnout △257 is removed, (414) introduced, and △413 assembled

(2) Track No. AT8 is no longer used and turnout △254 removed, while (413) and (414) are linked

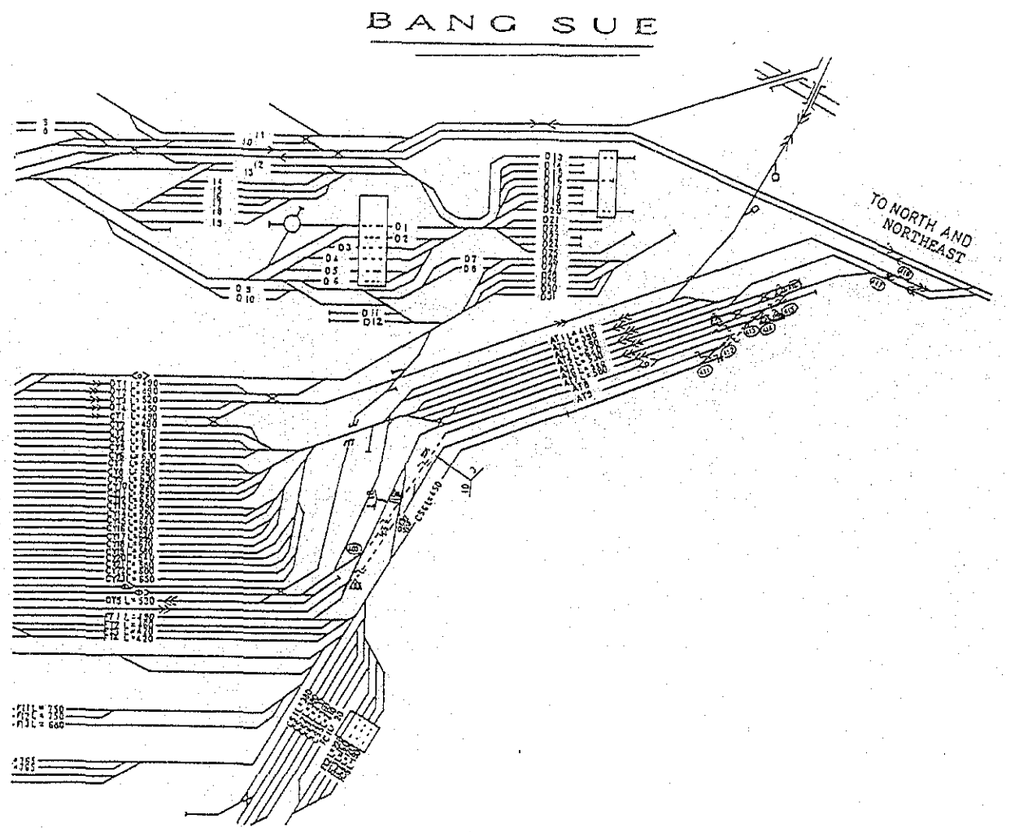


Fig. 4 The 2nd Changeover Work Diagram (Signals)

(1) Prior tests are performed
Control panel repairs
Wiring modifications

(2) An electric switch machine is newly provided for the introduced turnout (403)

(3) The electric switch machine is also moved with the transfer of turnout △185

(4) The electric switch machines are taken out with the removal of turnouts DSS △196 and △190

(5) Use of a part of the route for the related signal devices is suspended along with the disuse of route AT8

(6) The electric switch machines are removed with the installation of turnouts (411) and (412) and new ones installed

(7) The electric switch machines are removed with the installation of turnouts (410) and (418) and new ones installed

(8) The electric switch machines from the removed turnouts △259 and △258 are moved to the introduced turnouts (415) and (416)

(9) The electric switch machine from the removed turnout △257 is moved to the introduced turnout (414)

(10) The substituted signal device SS35 is removed

(11) The removed turnout △254 has its electric switch machine removed

(12) Along with the removal and insertion of turnouts, the track circuit is also newly constructed, removed, and reorganized

(13) Linkage tests are performed
Track circuit test
Railroad switch conversion test
Signal display test

(3) The 3rd changeover work

1) Track

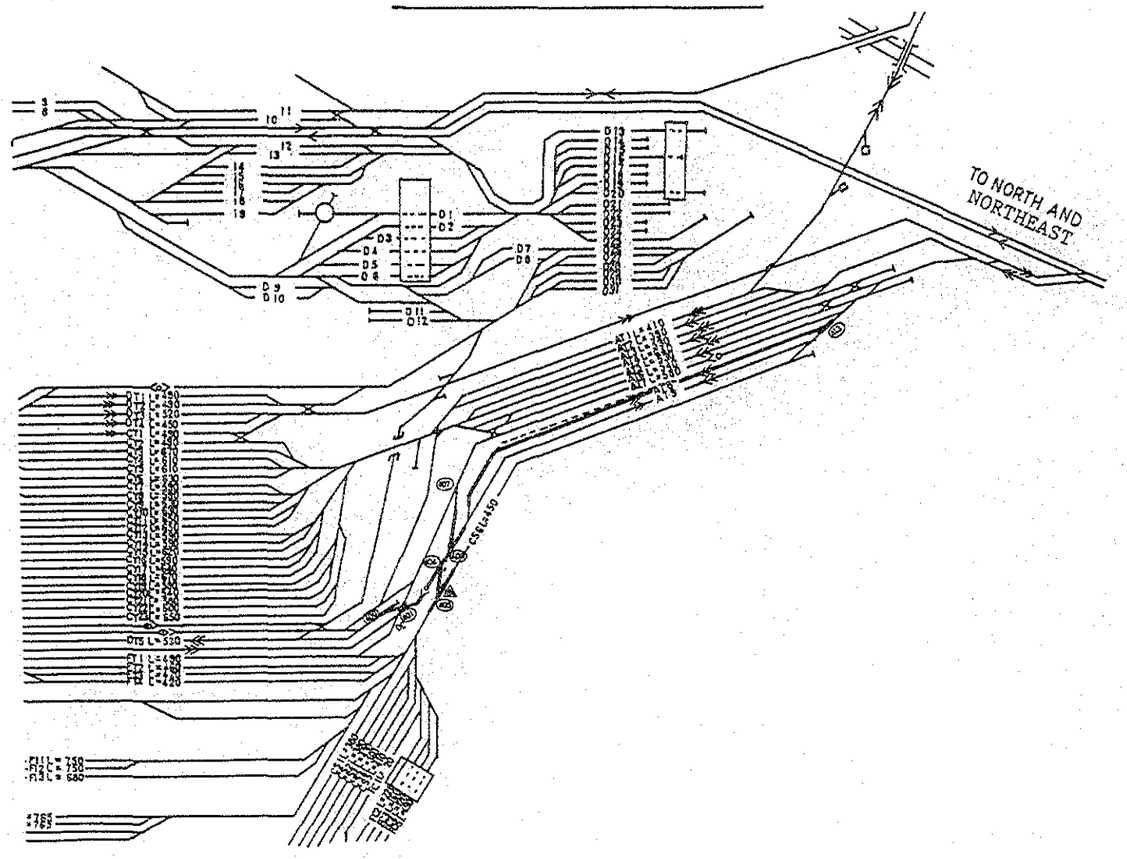


Fig. 5 The 3rd Changeover Work Diagram (Track)

3-1 Engine Route Improvement

(1) Turnout 184 is removed and 404, 405 and 406 introduced and linked to 407

(2) Turnouts 400 and DC 401 are introduced and linked to 404

3-2 Improvement of Track AT8

3-3 Commencement of the use of AT8 and AT9

(2) Introduction of turnout 413 and commencement of the use of AT8 and AT9

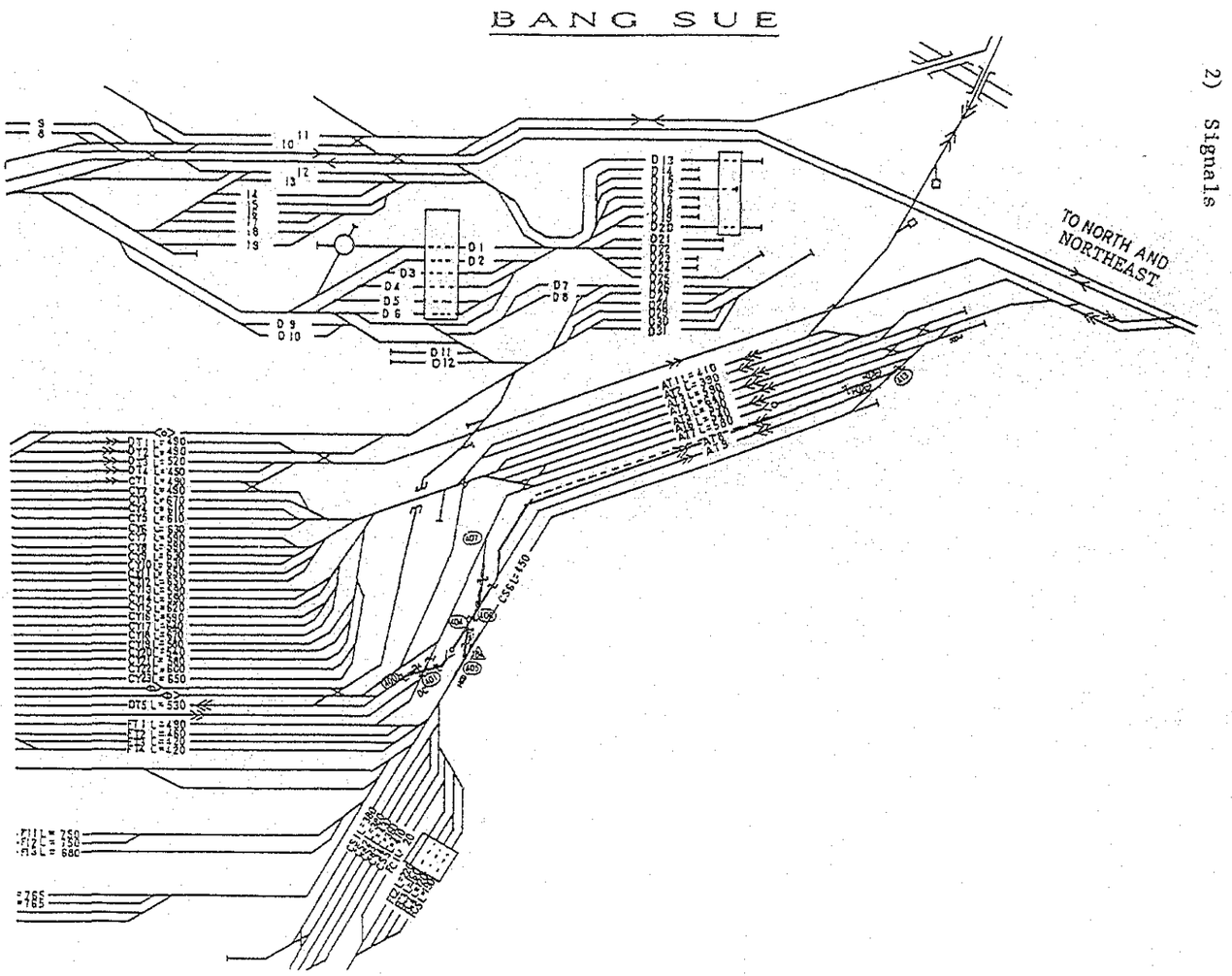


Fig. 6 The 3rd Changeover Work Diagram (Signals)

(1) Prior tests are performed
Control panel repairs
Wiring modifications

(2) The electric switch machine from the removed turnout (84) is moved to the introduced turnout (405).

(3) Electric switch machines are newly provided for the introduced turnouts devices (404) and (405).

(4) Electric switch machines are newly provided for the introduced turnouts (400) and (406).

(5) An electric switch machine is newly provided for the introduced turnout (413).

(6) Use of the departure signals newly constructed for AT8 and AT9 and for shunting signals at engine waiting track is begun.

(7) The shunting signal SS36 is relocated. The shunting signal SS39 is removed.

(8) Along with the removal and introduction of turnouts, the track circuit is also newly constructed, removed, and reorganized.

(9) Linkage tests are performed
Track circuit test
Railroad switch conversion test
Signal display test

Appendix 7.5.1 Yard Facilities at Hat Yai Station

Passenger and Freight Facilities

Track	Platform	Number of Tracks	Effective Length(m)	Track Number
Passenger arrival and departure	Yes	5	420 - 640	1 - 5
Freight arrival and departure, and Freight sorting	No	6	460 - 630	7 - 12
Passenger storage	No	4	90 - 190	28 - 31
Freight handling	Yes	4	110 - 270	15, 17, 32 and 33
Freight handling	No	10	90 - 220	14, 18, 19 and and 21 - 27
Freight storage	No	1	60	16
Weighing	No	1	220	13
Engine run - round	No	1		6
Draw - out	No	2	440 and 460	20 and 34

Car Depot Facilities

Track	Number of Tracks	Effective Length(m)	Track Number
Engine storage	6	70 - 380	D-1 - D-4, D-13 and D-14
Inspection	6	100 - 290	D-5 - D-10
Materials	3	100 - 160	D-11, D-12 and D-15
Draw - out	1	220	D-16

Appendix 7.5.2 Inadequate Effective Length for Freight Car Sorting and Storage Tracks

(1) Effective length of existing sorting tracks

Regarding the freight arrival and departure tracks, 3 tracks (tracks 10, 11 and 12) will be used for sorting. In Addition, tracks 13 and 16 will be used for storage.

Their effective lengths are:

Track 10 520 m

Track 11 410 m

Track 12 230 m

Track 13 230 m

Track 16 60 m Total 1450 m

(2) Number of freight cars handled: 230 cars/day.

(3) Turnover

24h/30.73th (mean stay time) = 0.78

(4) Mean freight car length: 8 m

(5) Required effective length

230 x 8 x (1/0.78) = 2360 m

(6) Effective length in shortage

2360 m - 1450 m = 910 m

(1) The 1st changeover work

1) Track

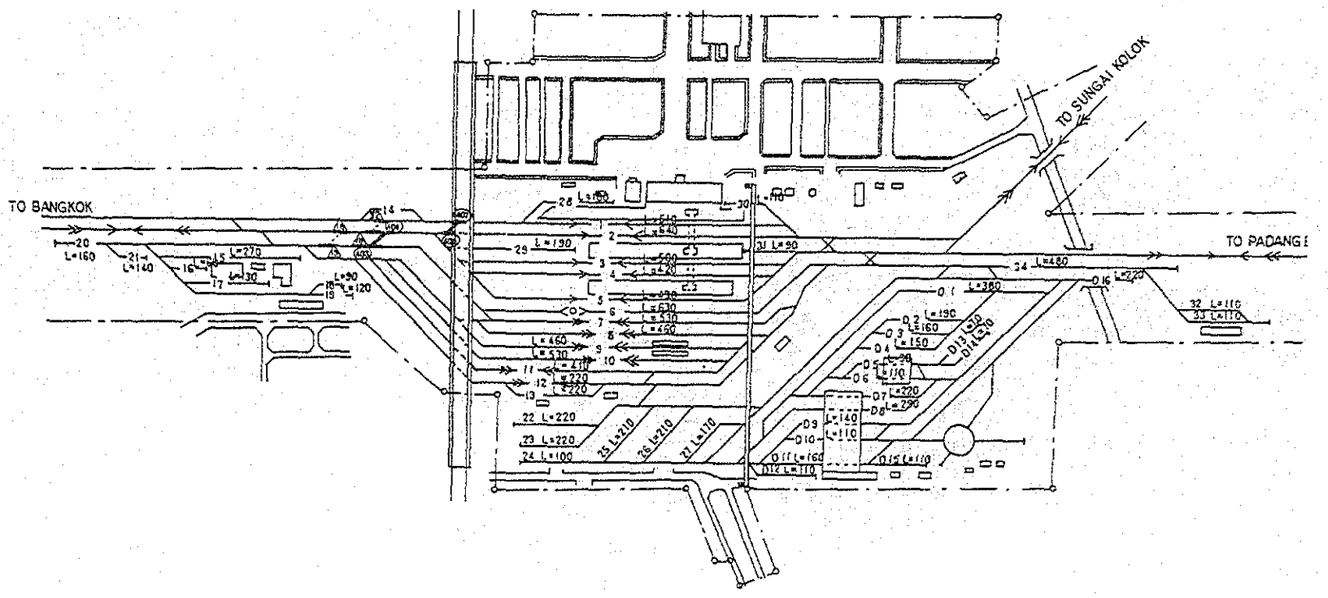


Fig. 1 The 1st Changeover Work Diagram (Track)

1-1 Change of arrival/departure track and draw-out route

(1) Turnouts (406) and (407) are introduced and connected together.

(2) Turnouts △18 and △92 are removed.

(3) Turnouts (403) and (404) are introduced.

(4) Turnouts △15 and △16 are removed.

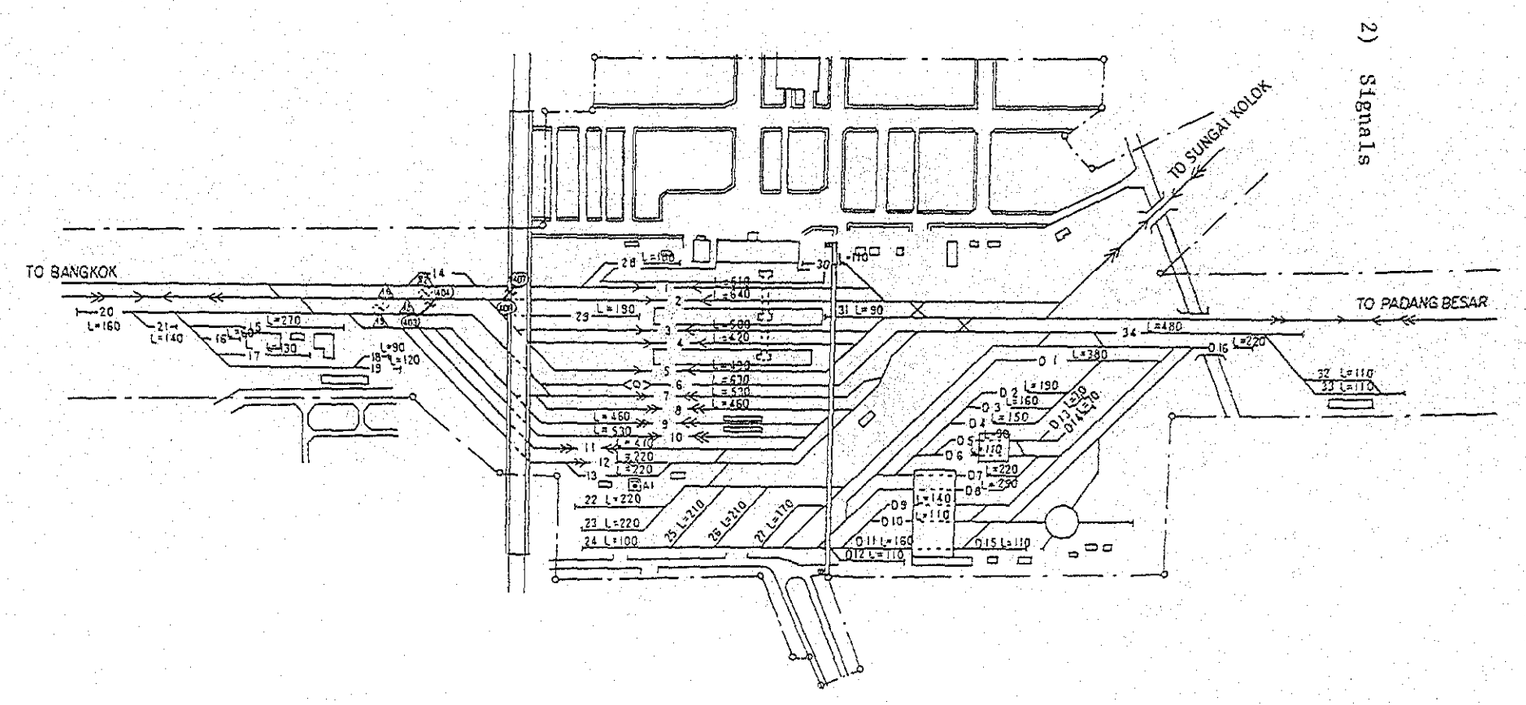


Fig. 2 The 1st Changeover Work Diagram (Signals)

In connection with converting the arrival/departure track and draw-out route, signalling facilities will be modified.

(1) Preliminary test should be conducted.
Modification of boards
Change of wire connection

(2) The electric switch machines of turnouts △92 and △18 are to be removed and reinstalled in turnouts (406) and (407), which are to be introduced.

(3) The electric switch machines of turnouts △15 and △16 are to be removed and reinstalled in turnouts (403) and (404).

(4) In connection with the removal or introduction of turnouts, track circuits should be modified.

(5) Interlocking tests should be made.
Track circuit test
Switch use test
Signal display test

(2) The 2nd changeover work

1) Track

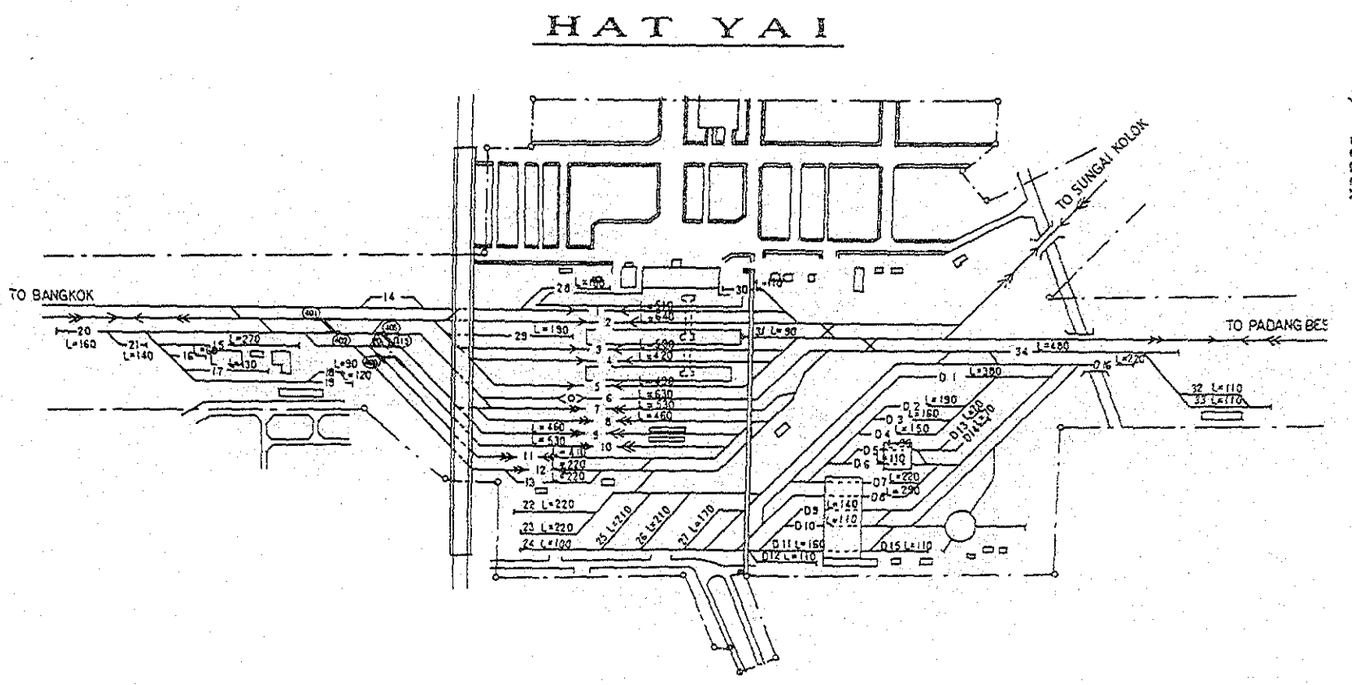


Fig. 3 The 2nd Changeover Work Diagram (Track)

2-1 Changing arrival/departure track of freight trains and arrival/departure route

(1) Turnout (408) is introduced.

(2) Turnout 20 is removed and (408) connected to track No. 10.

(3) Turnouts (405) and (415) are introduced and connected together.

(4) Turnouts (401) and (402) are introduced and connected together.

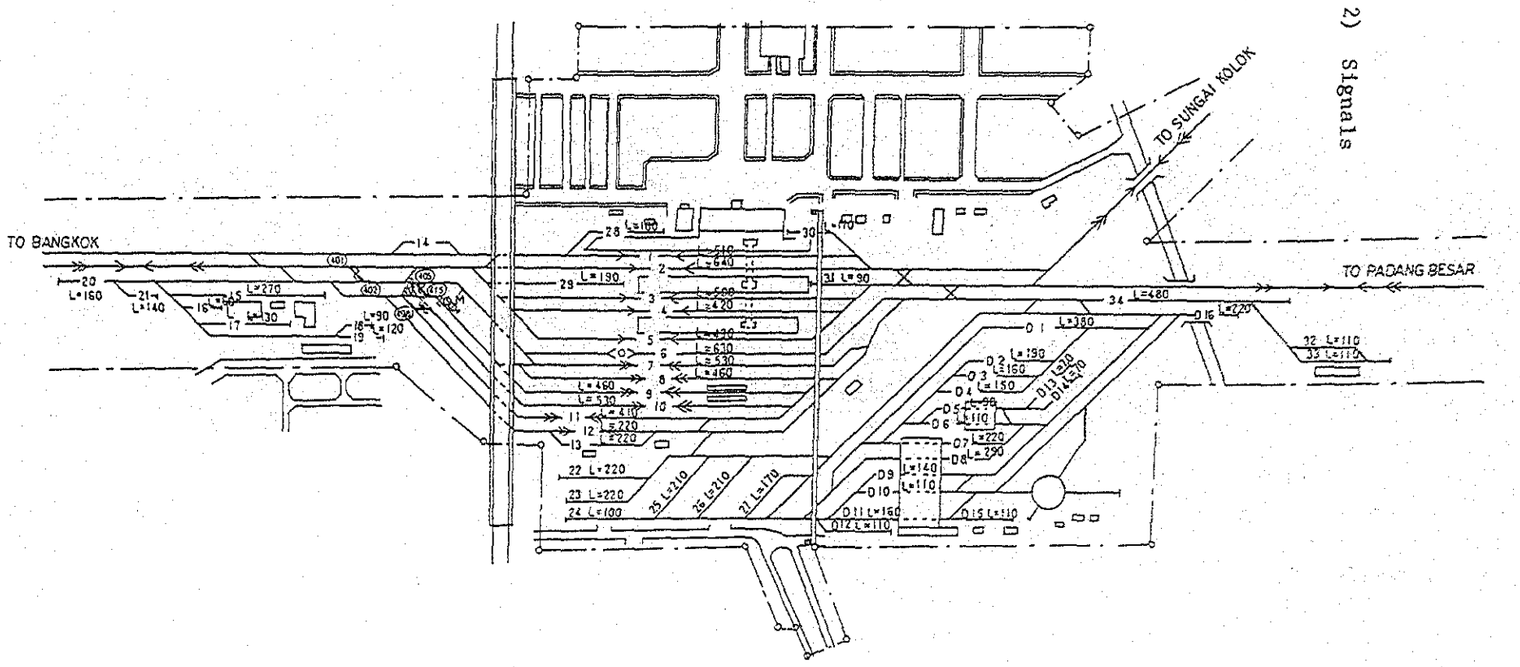


Fig. 4 The 2nd Changeover Work Diagram (Signals)

In connection with changing the freight train arrival/departure track and route, signalling facilities will be modified:

(1) Preliminary tests are conducted.
Modification of boards
Change of wire connection

(2) The electric switch machine in turnout (20) is to be removed and reinstalled in turnout (408), which is to be introduced.

(3) Electric switch machines are newly installed in turnouts (405) and (415), which are to be introduced.

(4) Electric switch machines are newly installed in turnouts (401) and (402), which are to be introduced.

(5) In connection with the removal or introduction of turnouts, track circuits are modified in composition.

(6) A starting signal device, M', is newly installed for trains leaving track Nos. 7 through 9 for Bangkok.

(7) Interlocking tests are conducted:
Track circuit test
Railroad switch use test
Signal display test

(3) The 3rd changeover work

1) Track

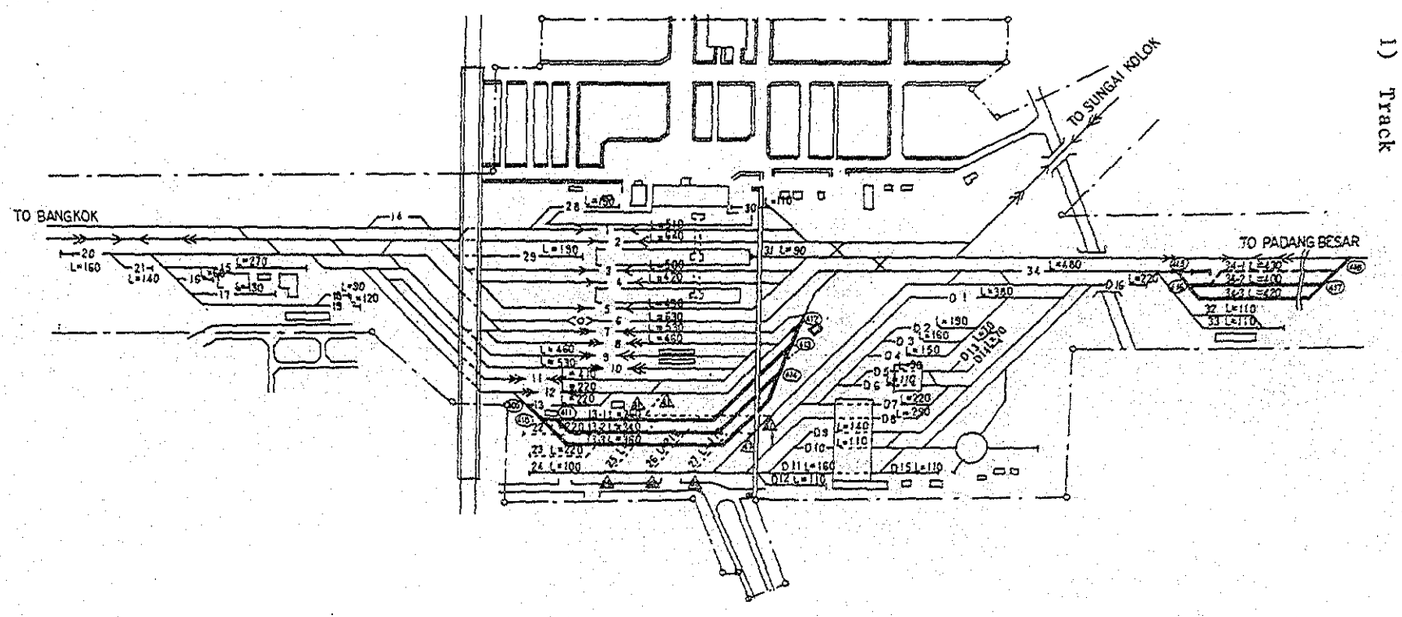


Fig. 5 The 3rd Changeover Work Diagram (Track)

3-1 Partial removal of freight facilities

Cargo loading/unloading track Nos. 22, 23, 25, 26 and 27 are removed.

3-2 Additional installation of sorting and retention tracks

(1) Removal and reinstallation of fuel supply facilities.

(2) Turnouts (409) and (412) are introduced.

(3) Track Nos. 13-1, 13-2 and 13-3 are also installed.

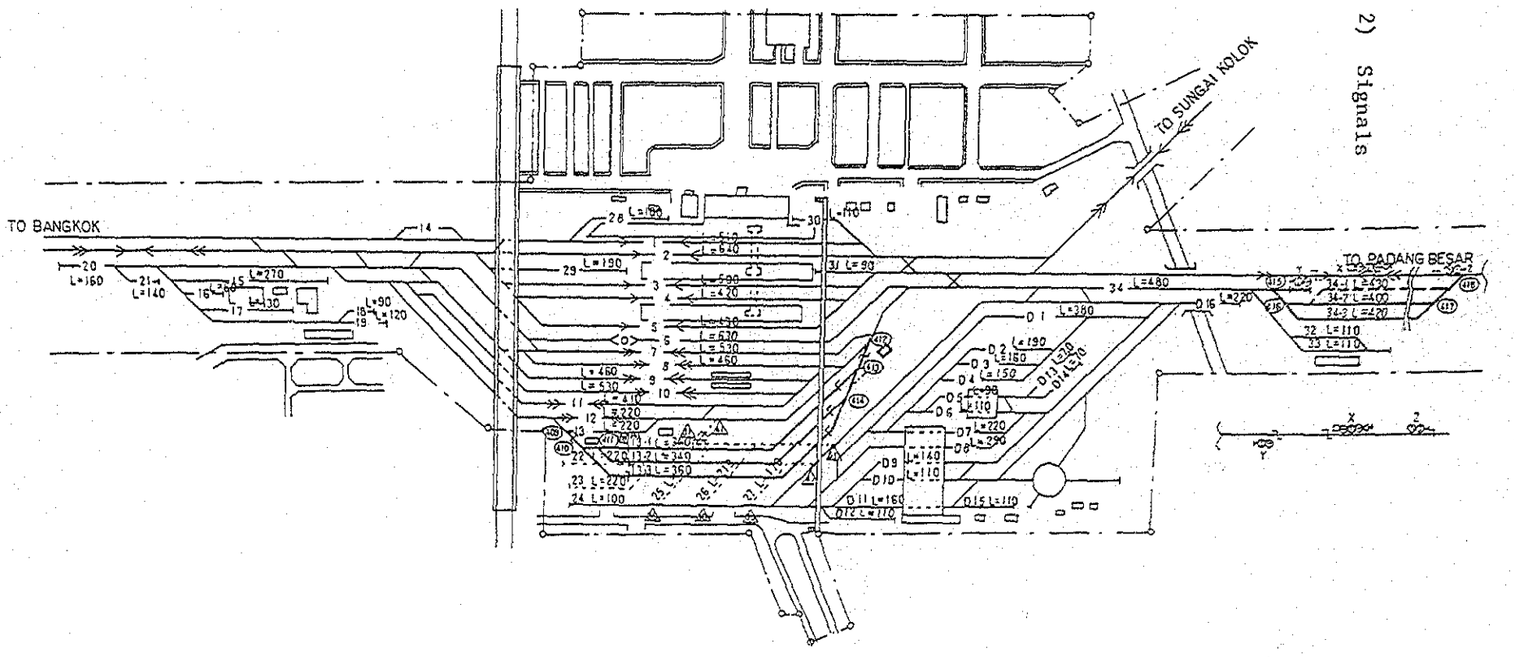


Fig. 6 The 3rd Changeover Work Diagram (Signals)

In connection with the partial removal of freight tracks, and addition of sorting and storage tracks, signalling facilities will be properly modified.

(1) Preliminary test
Modification of boards
Change of wire connection

(2) Electric switch machines are taken out from turnouts △31 and △41, which are to be removed.

(3) Electric switch machines are newly installed in turnouts (409), (410), (411), (412), (413) and (414), which are to be introduced.

(4) An electric switch machines is newly installed in turnout (418), which is to be introduced and connected to the Hayesderail.

(5) In connection with the introduction of (418), X, Y and Z signal units are moved to a reasonable distance.

(6) In connection with the removal and introduction of turnouts and relocation of signal units, track circuits are newly installed or modified in composition.

(7) Interlocking tests are conducted
Track circuit test
Switch use test
Signal display test

Appendix 7.6.1 Yard Facilities at Ban Phachi Station

Passenger and Freight Facilities

Track	Platform	Number of Tracks	Effective Length(m)	Track Number
Passenger arrival and departure	Yes	4	600 - 840	4, 5, 7 and 8
Freight arrival and departure	No	6	570 - 690	11 - 16
Passenger storage	No	8	170 - 480	1-3, 6, 9, 20, 29 and 30
Passenger and Freight passing	No	2	1,040 - 1,090	9 and 10
Freight storage	No	5	170 - 620	17, 18, 22, 23, 25
Engine	No	3	40 - 90	26 - 28
Draw - out	No	2	60 - 100	21 and 24

Appendix 7.6.2 Frequency of Train Operation Concurrency at Ban Phachi Station and Removal of Frequency

1. Conditions of Concurrent Operation and Frequency (Double circle represents removable frequency)

(1) Concurrent train operation is due to the passenger facilities and freight facilities being located across the main track

Norhern Line's passenger trains versus

Norheastern Line's freight trains: 10 times + 9 times = 19 times

◎ Norhern Line's freight trains versus

Norheastern Line's passenger trains: 8 times + 7 times = 15 times (Including 2 times already separated)

(2) Concurrent operating of passenger trains

◎ Northern Line "Down" versus

Northeastern Line "Down": 3 times

◎ Northern Line "Down" versus

Northeastern Line "Up": 3 times (Already separated)

Northern Line "Up" versus

Northeastern Line "Down: 1 time

◎ Northern Line "Up" versus

Northeastern Line "Up": 6 times

(3) Concurrent operating of freight trains

Northern Line "Down" versus

Northeastern Line "Down": 2 times

Northern Line "Down" versus

Northeastern Line "Up": 1 time

Northern Line "Up" versus

Northeastern Line "Down": 5 times

Northern Line "Up" versus

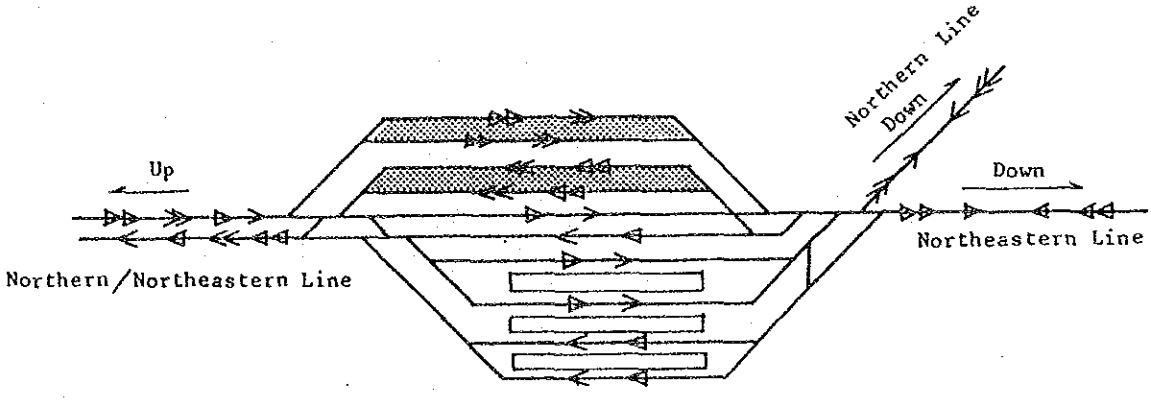
Northeastern Line "Up": 2 times

Total: 57 times (including 5 times already separated)

2. Removal Frequency (Double circle): 27 times

Frequencies of Concurrent Train Operations by Direction at Ban Phachi

Before \ After			Passenger Train				Freight Train			
			Northern Line		Northeastern Line		Northern Line		Northeastern Line	
			Down	Up	Down	Up	Down	Up	Down	Up
Passenger Train	Northern Line	Down			3		②		2	1
		Up	③		1	5	①	①	4	3
	North-eastern Line	Down			①		2	6	①	
		Up	(3)	1						
Freight Train	Northern Line	Down		①	1	(1)	①			1
		Up	②	②	4	(1)	①		2	2
	North-eastern Line	Down	1	1	①	①	2	3		
		Up	7		②				④	



Note: 1, Arrivals and/or departures within 10 minutes on the diagram were taken as concurrent a operation (minimum headway, 5 minutes).
2, A circle represents unavoidable ones due to a signal track on the same line.
3, Parentheses represent those already separated.