MIXED TRAFFIC TIMETABLE SIMULATION ANALYSIS: A CASE STUDY OF RED LINE COMMUTER TRAIN

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ABSTRACT

Long term plans for railways in Thailand include building metro and commuter lines in the Bangkok Metropolitan area. For identification purposes these are color-coded. The two Red Lines link Bangkok with suburban areas along north-south and east-west corridors. The expansion of the Light Red line to the west of Bangkok will terminate at "Salaya", with a spur line to "Siriraj". This will be the first network in Thailand on which electrified commuter and conventional long distance trains share tracks. This research investigates operational challenges between the different train types on the section from the main line terminal of "Bang Sue" to "Salaya" using a simulation model using OpenTrack program is asynchronous simulation. Study the possibility of using a shared rail and stations for train operation of different train types on the Red Line railway, including the impact on the various routes. The simulation showed that the different route reserving and releasing principles of the Light Red Line and the conventional line cause considerable capacity limitation along this main line sharing network. In the case of mixed traffic with only the commuter main line operations, the Light Red Line train can operate with a 10 minute-headway. If there is a need to use both commuter main and spur lines, only 15 minute headway can be achieved. The Light Red Line shuttle train service along the "Siriraj" spur line section should be considered in order to reduce the congestion effect caused by sharing tracks.

Key words: mixed traffic, timetable, simulation, OpenTrack, commuter line, Bangkok

1. INTRODUCTION

Most mixed traffic train services will be regional or intercity trains with both passenger and freight trains. Each train will have elements of a train set that can operate in different modes, to provide different origin and destination services, different train speeds and different patterns of station stops. In Germany high speed trains are also known as ICE (InterCity Express) and IC (InterCity). This type will only stop at main stations. RE (Regional Express), RB (Regional Bahn), S-Bahn will stop more than high speed trains. In Japan, Limited Express trains, Express and Rapid will have patterns of station stops that are different according to train type. Express trains, have fewer station stops. This type of service is different from Urban Rail Transit where the distance between stations is not as great and the service extent is less. The character of a homogeneous service provider is to stop at stations in the same manner without mixed traffic. The train service in cities mainly focuses on headway or frequency. Examples include the Tokyo Metro in Japan or U-bahn in Germany. Railway supervision in a city is often the responsibility of a local administrative agency that mainly looks after general public transport systems in a city. Intercity transport is often supervised by specific agencies for rail services. Some commuter trains are sometimes called urban-suburban rail: a train service that connects a city center with satellite town, such as the S-Bahn in Germany. The satellite town agency and intercity agency both have responsibility for services.

In Thailand, there has been a plan for railway services in the Bangkok Metropolitan Region since 1994 under the Mass Rapid Transit Systems Master Plan (MTMP). The first phase of this service plan is the Sky Train service: BTS. However, the service plan was improved, with the Mass Rapid Transit Master Plan in Bangkok Metropolitan Region (M-MAP). In 2010, the Office of Traffic and Transport Policy and Planning, developed the master plan for M-MAP with a 20 year phase (2010-2029). Some original routes have since been modified and the latest version of the plan is M-Map2. This does not have much adjustment or change. The overall route plan is still for approximately 500 km.

Management in Bangkok has special challenges because three agencies are responsible for project development: MRTA, Krungthep Thanakom, and SRT. The suburban train (Commuter train) is the main network focusing on passenger transportation between suburban areas within the urban area of Bangkok. In the future, it will connect with suburban trains that will expand to nearby cities in accordance with the study project.

The detailed design shows the suburban train system will operate mixed long distance trains. These will connect with the mass transportation system in the Bangkok Metropolitan Region (Rangsit-Ban Phachi, Makkasan-Chachoengsao, Taling Chan-Nakhon Pathom, and Mahachai-Pak Tho). The suburban railway system has 2 itineraries, sharing the rail with the long distance train system under the responsibility of SRT. The Red Line route has two parts: the Dark Red Line with running North-South/Southwest (Ban Phachi - Pak Tho); and the Light Red Line, which is a commuter train system that has both elevated and ground level sections. This run from East to West Bangkok.

Although some construction of the Light Red Line started in 2008, it has been delayed. There are many types of modifications, namely infrastructure, the number of tracks and the number of stations, including Bang Sue Junction station, which must also support high speed train services (Weerawat et al., 2020). It is expected to open for service as part of the commuter train service (Red Line train) in 2022. The section of the Light Red Line that connects Bang Sue junction station to the West line on the Salaya and Siriraj route is a path characteristically of mixed traffic. The single route in the master plan consists of long distance trains of the southern railway that originate at Bang Sue and Thon Buri, a freight train, and Red Line trains. There are many different operations, but trains will have to operate on the Red Line and use the stations together. The study route will have only 2 tracks for operating commuter trains, long distance trains and the freight train. Each has different operating characteristics, such as speed of trains, train types, different station stops, and unequal dwell times.

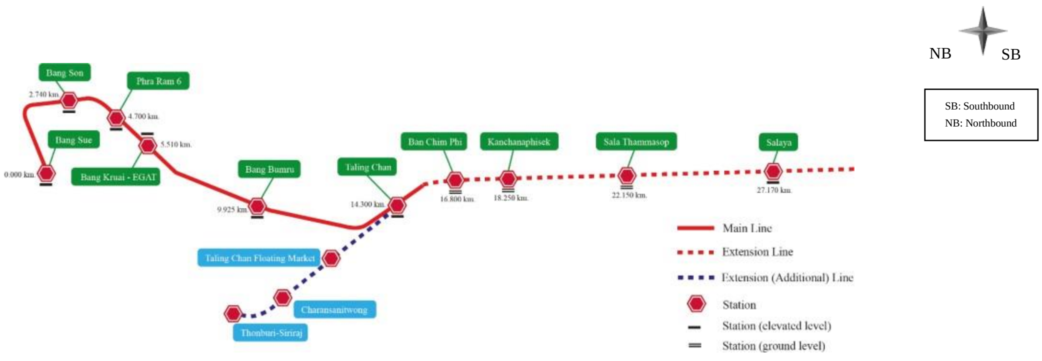


Figure 1. Red Line train route

Mixed traffic routes with long distance trains and a freight train are currently operating, and the Red Line train must be added into this service. A new track to support commuter trains must be added. The first part of the Project is the Bang Sue-Taling Chan section. Construction of the rail has been completed and it is expected to open for service in 2022. A new track and stations will be built in Salaya, Siriraj, and Taling Chan. In regard to this extension service plan (Spur line), the route services are mixed traffic. In the case of this Red Line study, there are many challenges in terms of service capabilities. The service includes both diesel trains and electric trains operating together, with commuter trains, express trains, rapid trains and a freight train. All trains have different service capabilities. In service, conventional trains do not use the ATP system. Also reservations are managed station to station, which is different from the Red Line train. That uses the ETCS level 1 system reference, which can reserve fixed blocks by track. This research will investigate details of the possibilities of mixed traffic service: joint transportation between conventional and electric trains. This is the first route in Thailand this will operate on. This research will use a computer program in the study to assess the possibility of using a shared rail and stations for train operations of different train types on the Red Line railway under actual operating conditions using the defined operating plan.

2. RELATED RESEARCH

For track allocation of shared rails without conflicts, the problem of train journeys or problems in scheduling routes that occurs must be known so the potential patterns of train journeys can be analyzed. The main application of track allocation for a train journey using shared rails determines the best operating schedule of the timetable (Borndorfer et al., 2012).

Railway journeys that have conflicting rail links are a major problem, and simultaneous running is difficult to resolve in a timetable (Schlechte, 2007), due to the complexity of operations. Because of the variety of modes of transportation, infrastructure that requires turnouts and signals to provide solutions for the variety of operations. This is a complex problem and there are many factors to consider (Huisman et al, 2005), Caprara et al. (2007) for the operating model.

There are many methods of train journey analysis. These can be divided into analytical methods and simulation methods (Pachl, 2002). Both have advantages and disadvantages. Analytical methods do not need a detailed schedule, and can establish a long-term plan without a timetable. The disadvantage is that it looks simple and does not consider the consequences. The simulation method can show details of the effects, as well as more information about the timetable, infrastructure, and trains. This usually provides more accurate results and covers full details.

There are manymethods of adjusting and increasing the possibilities of operating mixed traffic. The most popular method is rescheduling. This can be adjusted in four ways: re-routing; adjusting the running time or dwell time (equivalent to adjusting the arrival and departure times); adjusting the sequence of trains at the station; and re-servicing. Choosing an appropriate method depends on the infrastructure. Research related to mixed traffic uses different methods to resolve conflicts according to the manner of the problem. Re-routing methods (Wegele et al., 2008), (Fan, 2012) are used to manage a train that has caused conflicts and then changes to a new route. This method can be used, but the route must have more than 2 tracks. It the best method to handle conflicts. Some research combines methods for re-routing and changing running times (Tornquist and Persson, 2005), (Kersbergen et al., 20014) to adjust the pattern of the train journey. Methods to change the running time and the dwell time (Breusegem, et al., 2014), (Assis and Milani, 2004) affect the timetable most. The method for adjusting the new service will consider only operation in the urban area or the various patterns of operation with a high frequency of departure times (Favech, 2003), (Zidi, 2007). These common methods, and the methods most researched, are considered when modifying conflicts. These methods are used in the simulation as follows: to increase the number of trains that can be operated from origin to the destination, which can be done by adding routes and adding platforms (Rangarai et al., 2003); or to change factors that influence a variety of trains, such as train speed, tractive effort, and the priority of the train (Dingler et al., 2009); selection of the schedule with a different route based on train capacity, by increasing and reducing the frequency of express train services (Zheng et al., 2009). When a freight train stops on the passenger train route it should be possible to add new routes and increase dwell time at the station (Vidyadhar et al., 2017). When the train has different speeds it can be set so that fast trains overtake slower trains by having the slow train stop at the side track or station (Zhang et al., 2015). Methods of increasing the number of trains for mixed traffic, can be done by changing the timetable (Luethi et al., 2007).

This research used methods of increasing the speed of trains, overtaking, and rescheduling. The increase in train speed was done by adjusting the train performance to operate at the highest speed. It allows fast trains to overtake slower trains at stations as there are only 2 tracks for the study route. The station has a main platform and a side platform, therefore the slow train waits at the main station. For the fast train to use the route first, rescheduling methods have to change dwell time, arrival and departure times, and add additional station stops for long distance trains. However, the method used for adjustment must take account of the infrastructure of the route with the original operating pattern of the train currently operating.

3. RESEARCH METHODOLOGY

The route service from Bang Sue to Salaya provides mixed traffic. There are 3 types of trains on this route, consisting of commuter trains and intercity trains: both passenger and freight transport. The master plan was prepared in three separate parts which were not integrated. It did not therefore consider trains on different control systems for conventional trains and electrified trains. Due to the signaling improvement plan, the adjustment of the train is not consistent with the consideration of Parts Two and Three, which were designed after the First Part had been built successfully.

As shown in Figure 1 the studied route must support the meter gauge in the future. The route details are divided into 3 parts:

Part 1: The route from Bang Sue to Taling Chan station (distance of 15 kms) has 6 stations: Bang Sue, Bang Son Phra Ram 6, Bang Kruai-EGAT, Bang Bumru and Taling Chan.

Part 2: The route from Taling Chan station to Salaya is a railway line extension (distance of 14 kms) and has 4 stations: Ban Chim Phli, Kanchanaphisek, Sala Thammasop and Salaya.

Part 3: The railway line from Siriraj will be operated on the main route using shared stations. These include: Taling Chan, Ban Chim Phli, Kanchanaphisek, Sala Thammasop and Salaya.

In this research, the situation is analyzed under current and studied resources using a computer model, to answer the question of how to operate the railway with mixed traffic, and how to use shared rails and stations. For the simulation, the researcher has applied the OpenTrack program for analysis. The overall scenario in the simulation is done by finding the running time of a single train mode compared to a network train in various formats. That can operate under various headways according to the operating conditions. The model needs to be consistent with the Red Line train (RL) that can operate at up to 160 kilometers/hour. There are 30 second dwell time stops for each station. The long distance train (LD) with 2 types of speed trains runs at 120 kilometers/hour or 100 kilometers/hour. There are different station stops. The freight train (F) has a speed of 100 kilometers/hour. As shown in Table 1, the study time period is 6.00-10.00 am, which is the time period with the densest volume of long distance trains and freight trains on the route.

Table 1: Engine train

Data	Value				
Train No.	**43**	**261**	**781**	**32,84,171,172,255,257,260**	**RL**
Engine name	Sprinter Driver car Sprinter Non Driver car	THN Driver car THN Non Driver car	CSR Locomotive	Hitachi Locomotive	Commuter Red Line
Type	DMU	DMU	Diesel Electric Locomotive	Diesel Electric Locomotive	Red Line RST Hitachi
Load (Tons)	38.906 (Driver car) 37.730 (Non driver car)	35.322 (Driver car) 33.500 (Non driver car)	120	90	297
Adhesion Load (Tons)	38.906 (Driver car) 37.730 (Non driver car)	35.322 (Driver car) 33.500 (Non driver car)	120	90	297
Length (Meters)	21	21	20	20	120
Maximum speed (km/h)	120	100	100	100	160
Maximum Tractive Effort (kN)	141	46	468	270	304
Resistance factor	3.3	3.3	3.3	3.3	3.3
Rot mass factor	1.06	1.06	1.06	1.06	1.06
Max Acceleration (m/s^2)	1	1	3	3	0.89

The operation plan for the Red Line uses three train types. The commuter train (Red Line train) runs on 4 routes from Bang Sue-Salaya, Salaya-Bang Sue, Siriraj-Taling Chan-Salaya, and Salaya-Taling Chan-Siriraj with normal operations controlled by fixed block. There are four long distance trains routes: Bang Sue-Salaya, Salaya-Bang Sue, Thonburi-Ban Chim Phi-Salaya, and Salaya-Ban Chim Phi-Thonburi. The freight train has one route, from Bang Sue-Salaya, as shown in Figure 2. The simulation section of the Red Line trains and long distance trains is outside the scope of the study and will not be included in the simulation to that station, which will simulate only from Bang Sue-Salaya station. The total distance is 27.170 kilometers and there are 10 stations, as shown in Figure 1. The Red Line train uses a side platform at the station. Long distance trains use the main platform. The freight train does not stop at stations on this route and uses the main line for service (Figure 3).

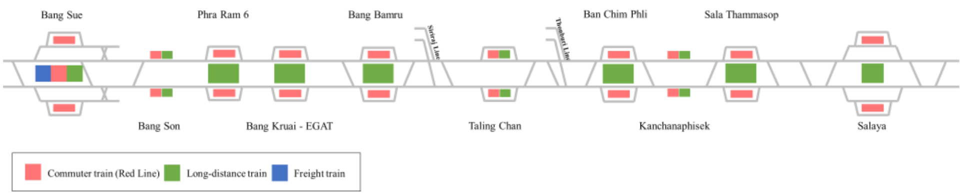


Figure 2. Track outline of Red Line

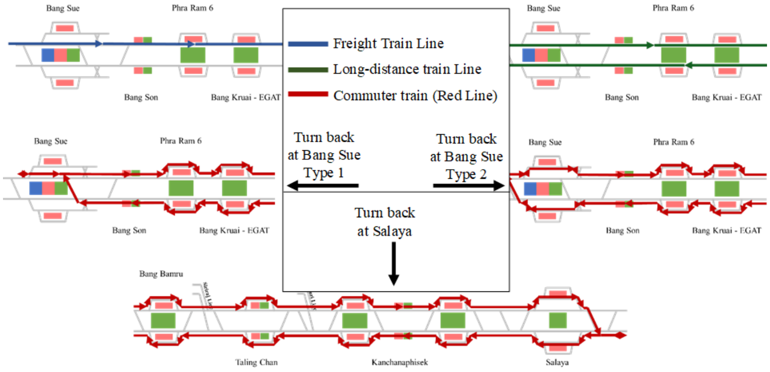


Figure 3. Train route characteristics

As shown in Figure 3, the Red Line train has 2 turnback types at Bang Sue station: Type 1 turnback at the switch before entering the station with 1 Platform used; Type 2 turnsback through the turnout after Bang Sue station using 2 platforms for operations. At Salaya station there is a turnback through the turnout after the station using 2 platforms for operations. The manner of the station stop of the Red Line depends on the train type. Commuter trains stop at all stations. Long distance trains stop at some stations. The freight train (No.781) is non-stop (Figure 4). There are four types of long distance trains: special express train (S) No. 43 and 32; express train (E) No. 84; rapid train (R) No.171 and 172; and ordinary train (O) No. 260 261 255 257. These show the same station stop pattern as in Figure 5 (below).

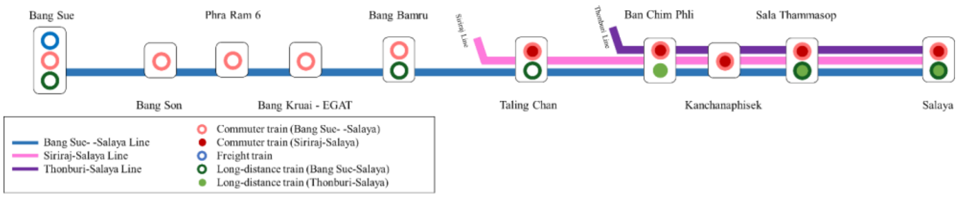


Figure 4. The station stop manner of Red Line

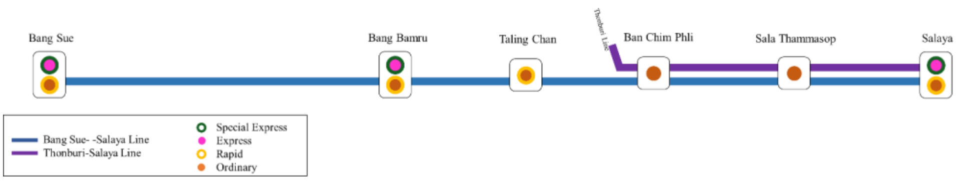


Figure 5. Long distance train station stop pattern

3.1 Simulation

The Red Line train routes, have different modes of operation with limited routes resulting in different simulations of various situations to demonstrate the operating characteristics with the possibility of various patterns of mixed traffic and the impact caused by trains. This starts by verifying the infrastructure information. The complex infrastructure of the Red Line project has been changed many times. All models have been checked for various positions, such as station position, turnout position, signal position, curves, and gradients for further modeling. The actual operating times under current conditions have been validated by simulating long-distance trains and freight trains. These are used in the simulation as follows:

3.1.1 Single train

The train journey of each train types from origin to destination as a single train in the system, in order to find the travel time by covering all trains and itineraries.

3.1.2 Network train

1. Homogenous traffic is trains run at the same speed and have identical stop patterns is straightforward. Simulation situation are:

Scenario A: trains run between Red Line trains main line (RL1) with Red Line train main line (RL1). The situation was with a Red Line train on the main line (Bang Sue-Salaya) of the railway route with a train of the same type that has the same traveling characteristics.

Scenario B: trains run between Red Line trains main line (RL1) with Red Line train spur line (RL2). The situation was with Red Line trains on the main line and the spur line to share routes with a case of the same train type. It has the same traveling characteristics but with different origin routes.

2. Mixed traffic train journeys have various patterns: long distance trains, the freight train and Red Line trains. Red Line trains run from Bang Sue to Salaya (main line) and from Siriraj to Salaya (spur line). For Red Line trains, only the main line is in the simulation framework and the only route has a round trip. This is to find a mixed traffic pattern that is suitable for the Red Line route. The behavior of the train includes characteristics of reserves and releases, as well as any differences in operating characteristics and train types. Simulation situation are:

Scenario C: Mixed traffic between RL1 with long distance trains (LD) and freight train (F). The situation shows mixed operation between long distance trains and the freight train with Red Line trains on the main line (turnback at Bang Sue type 1) in the case of different train types. These have different train characteristics but use the same route.

Scenario D: Mixed traffic between RL1 and RL2 with long distance trains (LD) and freight train (F). The situation is mixed operations between long distance trains and the freight train with the Red Line trains on both main line (turnback at Bang Sue type 1) and spur line. In the case of the different train types, these have different train characteristics but use the same route. Trains that use the same origin-destination route may have different train types. There are different train types with trains that use different origins but the same destination.

4. RESULTS

4.1 Single train

Running Time: The time of exiting the previous station until entering the next station.

Travel Time: The duration of train travel on one itinerary, from departure time of the train at the origin station until arrival time at the destination station.

Dwell time: The duration of a train stop (speed 0 km/h) at various stations or U-turn positions.

Table 2 shows different running times for each train type because there are different train speeds, train loads, and station stops. The same train types southbound and northbound have different running times. This is caused by the gradient of the infrastructure, so these limitations affect mixed traffic trains.

Table 2. Running time of each train types

RL		Train No.				Direction	Station to Station	Direction	RL		Train No.			
		LD (S)	LD (O)	LD (O/T)	F						LD (S)	LD (E)	LD (R)	LD (O/T)
RL1	RL2	43	261	255,257	781				RL1	RL2	32,38+46	84	170,172	260
2.07		8.35	9.43		37.35		Bang Sue to Bang Son		2.41		8.55	10.35	10.35	
1.57							Bang Son to Phra Ram 6		2.00					
1.09							Phra Ram 6 to Bang Kruai - EGAT		1.10					
3.05							Bang Kruai - EGAT to Bang Bamru		3.13					
3.26		13.48	4.48				Bang Bamru to Taling Chan		3.25		14.17	17.08	5.15	
2.14	2.14		8.07				Taling Chan to Ban Chim Phli		2.14	2.14			13.05	
1.40	1.40			4.22			Ban Chim Phli to Kanchanaphisek		1.40	1.40				4.47
2.56	2.56						Kanchanaphisek to Sala Thammasop		3.00	3.00				
3.19	3.19		5.25	3.29			Sala Thammasop to Salaya		3.23	3.23				4.35
21.53	10.09	22.23	28.03	7.51	37.35		**Travel Time (MM.SS)**		22.46	10.17	23.12	27.43	28.55	9.22
26.53	12.09	26.23	33.03	10.51	-		**Travel Time+Dwell Time (MM.SS)**		27.46	12.17	27.12	31.43	33.55	12.22

*RL=Red Line train {RL1=Main Line,RL2=Spur Line}, F=Freight train, LD=Long-distance train {(S)=Special Express (E)=Express (R)=Rapid (O)=Ordinary}, O/T= Ordinary /Thon Buri

4.2 Bottleneck

The Red Line has 4 caution zones in relation to entry and exit of the new trip, as shown in Figure 6.

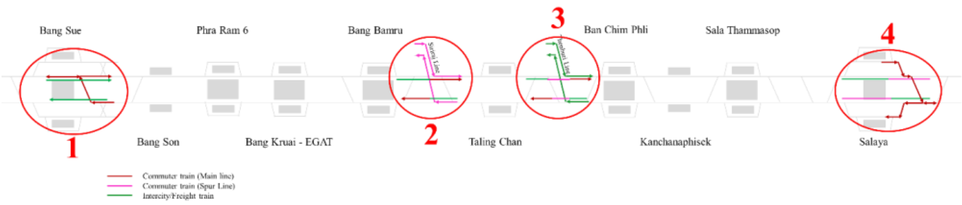


Figure 6. Bottleneck of Red Line route

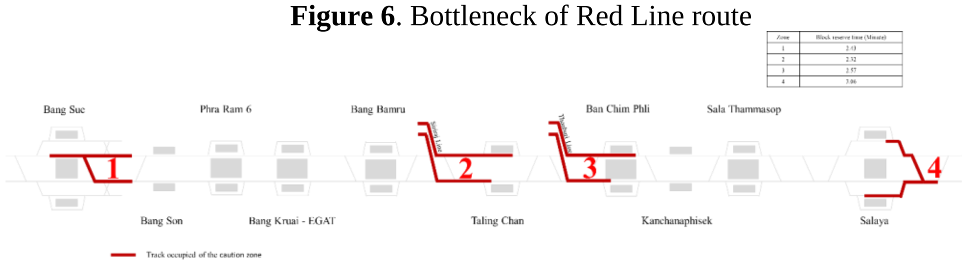


Figure 7. Occupied position of caution zone on the track

Figure 6 shows 4 zones of the points of a trip change in the route which could affect the train and is usually a bottleneck. Figure 7 shows the occupied positions of caution zones on the track.

Zone 1: Bang Sue station has a turn back at the switch before entering the station with 1 Platform used. This results in the track being occupied for a long time: up to 2.43 minutes (Figure 7). Long distance trains and a freight train pass through at the same time as the turn back of Red Line trains. In this case, the U-turn train turns back through the turnout after Bang Sue station to reduce the density of the route.

Zone 2: Interchange to Siriraj (Spur Line) of Red Line trains. The train moves to the main line to wait for the train to change the timetable, or waits for the route release in order to use the path. Since it is an interchange, track is occupied up to 2.32 minutes (Figure 7). In this case, the spur line is used to operate a shuttle train.

Zone 3: Interchange to Thonburi: position of long distance trains occupies the track for 2.57 minutes (Figure 7), since it is a joint point with another long distance railway.

Zone 4: Salaya station has a turn back through the turnout after the station and uses the same timetable as long distance trains/freight train so the track is occupied at this point for 3.06 minutes (Figure 7).

4.3 Network train

Table 3. The simulation results of network train scenario

Scenario		Red Line train: Headway						Long distance train/Freight train		Number of train Red Line
		RL 1			RL 2			Use Train	Additional runtime (MM.SS)	
		6	10	15	6	10	15			RL 1
Scenario A	SA_01									10
	SA_02									6
	SA_03									4
Scenario B	SB_01									
	SB_02									
	SB_03									
	SB_04									6
	SB_05								0.30 - 2.30	6
	SB_06									4
Scenario C	SC_01							/		
	SC_02							/		
	SC_03							/	0.30 - 4.00	4
Scenario D	SD_01							/		
	SD_02							/		
	SD_03							/		
	SD_04							/		
	SD_05							/		
	SD_06							/	0.30 - 7.30	4
Scenario E	SE_01							/	1.00 - 9.45	6
	SE_02							/	2.00 - 10.00	6
Scenario F	SF_01							/		6
	SF_02							/		4
	SF_03							/	2.00 - 8.00	6
	SF_04							/	0.30 - 2.30	4

Conflict free
Reduce speed
Cannot operation

RL 1 : Commuter train (Main line)
RL 2 : Commuter train (Spur line)

4.3.1 Initial plan: homogeous traffic

4.3.1.1 RL1 Only (Scenario A)

The simulations of RL1 and RL1 use the same type of train, the same operation, the same origin-destination, the same pattern service, and a stop at every station for 30 seconds. The reserves and releases are track to track so there can be a few changes with headways of at least 3.30 minutes, or 17 train per hours, in accordance with the former 6 minute plan.

4.3.1.2 RL1+RL2 (Scenario B)

Scenario B has mixed traffic of only Red Line trains in both itineraries (RL1 and RL2). They have the same operation service pattern and stop at every station for 30 seconds, but have different origins. RL1 has its origin at Bang Sue station and RL2 originates from Siriraj. RL2 joins the trip at Taling Chan station. The track to track reserves and releases with 6 minutes headway cannot operate but can operate at 7 minutes headway in both itineraries.

4.3.2 Initial plan: mixed traffic

4.3.2.1 RL1+LD+F (Scenario C)

Scenario C has mixed traffic between RL1, LD, and F. When a long distance train and freight train are inserted into the route, reserves of long distance trains are station to station and releases are track to track. As a result, the distance requires a sufficient headway for Red Line trains. If the reserves are different, as shown in Figure 8, in the case that the long distance trains follow Red Line trains, the block distance must not overlap. Important block distances are on the Sala Thammasop-Salaya section. For the Red Line trains to follow long distance trains, the caution period is the first phase of the route: the Bang Sue-Bang Son section as shown in Figure 8. This is because the Red Line trains have higher speeds than long distance trains.

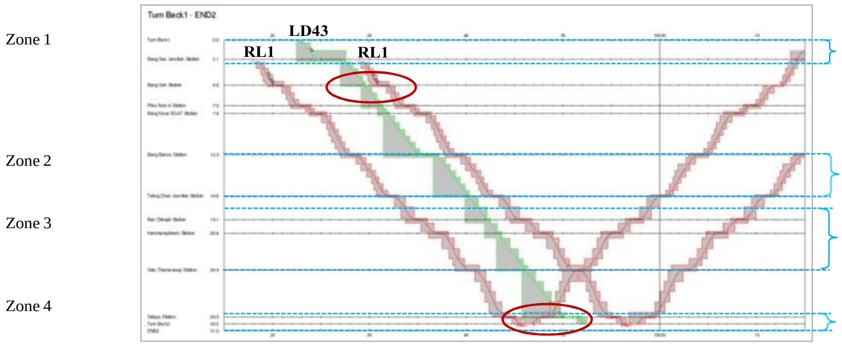
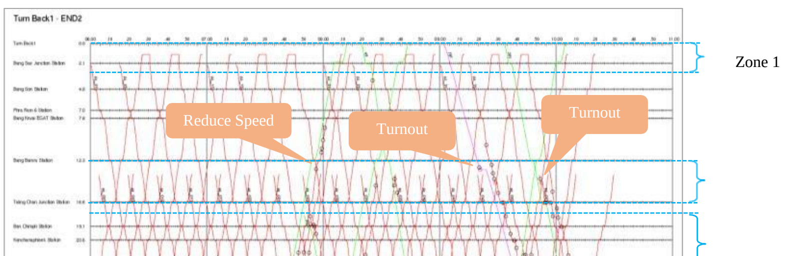


Figure 8. Train diagram for route occupation of long distance train No. 43 with Red Line train (RL1)

4.3.2.2 RL1+RL2+LD+F (Scenario D)

Scenario D has mixed traffic between RL1, RL2, LD, and F. Reserves of long distance trains and Red Line trains have different behaviors as follows RL reserves, with track to track; and LD, F reserves are station to station. The result is that only scenario D_06 (Figure 9) can operate. It uses train RL: 4 trains per hour (2 trains each direction), but Red Line trains have reduced speed for keeping headway, and long distance trains need to reduce speed at turnout zones 2 and 3.

Mixed traffic is complex because of the route reserves. The Red Line train has reserves track to track, while long distance trains have reserves station to station. Although the RL1 and RL2 trains have higher speeds than long distance trains and the freight train, the RL train stops at every station. Some LD have journey times faster than the RL and different track reserves responsible for the Red Line train that block space will be reserved more than for long distance trains and the freight train. Thus long distance trains and the freight train cannot be inserted at few headways.



Zone 2

Zone 3

Zone 4

Figure 9. Train diagram (SD_06)

4.3.3 Improving capacity

1. Reduce travel time by increase speed of train performance.
2. Reschedule: increase dwell time or station stop of LD by do not affect both previous and after fro RL trains.
3. Overtaking: adjusted to allow RL trains overtake LD trains at the station to avoid reduce speed of both RL and LD trains.

4.3.3.1 Scenario : Can not operate (Scenario E)

In the case that trains cannot operate because of the manner of the turnback (Zone 1), it attempted to change the turn back to Type 2 or turn back through the turnout after the station to reduce the load on infrastructure. The result is that the Red Line trains can be operated with long distance trains and the freight train, but have reduced speed in Zones 2 and 3 caused by changing the route. Zone 4 occurs at the turn back behind the turnout after Salaya station, because of the reserve times of long distance trains and the freight train near the Red Line trains.

4.3.3.2 Scenario : Reduce speed (Scenario F)

In the case that the train has reduced speed because of keeping headway, increasing the speed of LD and F train was tried. Rescheduling allowed Red Line trains to overtake LD and F, adjust arrival and departure times of LD and F, and adjust increase dwell times of LD and F. In SF_01/SF_02, the result is that the Red Line trains can operate with long distance trains and the freight train.

SF_04 is mixed traffic between RL1, and RL2 at headway 15 minutes with LD and F. The number of trains of RL1 is 4 trains per hour (2 trains each direction). The train is adjusted to avoid reduced speeds, as shown in Figure 10. It is evident that some trains have reduced speed, due to the different operation patterns and the time to increase the speed of long distance trains and the freight train, adjusting arrival and departure of long distance trains and the freight train. These increase station stops, as well as dwell times of long distance trains and the freight train. As a result the additional run time can be increased, but some trains have reduced speed.

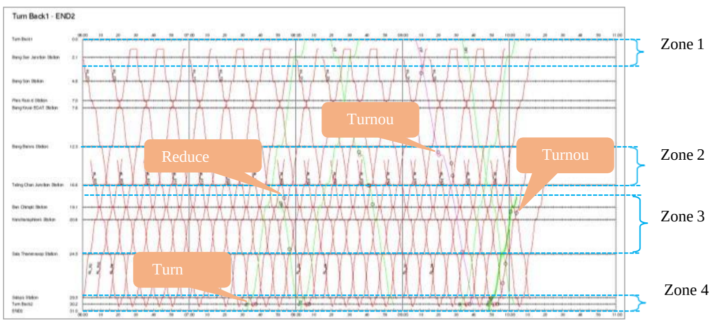


Figure 10. Train Diagram (SF_04)

5. CONCLUSIONS

From the study of train operation on mixed traffic of long distance trains and a freight train with the Red Line trains, when train types have different speeds, different operation patterns, and different reserves and releases, mixed operating affects train journeys considerably. In this regard, the researcher has simulated various operations as follows.

For only Red Line trains operations, reserves and releases are track to track and the result is that trains can operate with less headway. The train journey on the Bang Sue-Salaya section of the mainline route, can provide service when long-distance trains are not included at headway from 6 minutes. Mixed traffic between RL1 with RL2 will result in double the station headway from Taling Chan-Salaya. If mixed traffic between RL1 with RL2 at headway is defined as 6 minutes it can not operate. Operation of headway from 7 minutes or more is recommended with turn back through the turnout after Bang Sue station, or about 8 trains per hour (4 trains each direction). It should not reach 10 trains per hour according to the original service plan.

In the case of the Red Line trains, there is a higher demand for services: there is mixed operation of the Red Line train in both directions. It is suggested that the frequency of service for each route is 7.30 minutes (7.5*8 = 60 minutes). There are therefore 8 trains per hour with 4 trains each direction.

As for the mixed traffic, the manner of reserves and releases will be different, as follows. In the operation of long distance trains or the freight train followed by Red Line trains, reserves of LD are station to station and releases are track to track. The control will be a fixed block, controlled according to the signaling. The drivers must control the train themselves. Both reserves and releases are track to track as Red Line trains have an Automatic Train Protection (ATP) system, controlled by the control center. It is a safe distance control system for trains, controlling the speed of the train at a safe level. The operation in this case will result in overlapping of the schedule because the Red Line trains are faster than long distance trains. In the case of Red Line trains followed by long distance trains or the freight train, reserves and releases of LD have the same characteristics as in the above case, but Red Line trains stop at more stations than long distance trains resulting in a schedule overlap at the destination section. This is especially the case during the longest time of reserves which are the Sala Thammasop-Salaya section. In the case of a long distance train followed by a long distance train, reserves and releases are both station to station, but in this case, it will not be found in the simulation because LD is a train that does not operate as often as the Red Line trains: when mixed traffic at reserves and releases is inserted between station and track.

In the case of mixed traffic between LD, F, and RL at headway (RL), 10 minutes or 6 trains per hour, the primary service plan uses turn back of Red Line trains at Bang Sue station at the switch before entering the station so cannot operate. As Red Line trains have ATP, when mixed with long distance trains this results in additional runtime. It is recommended that the U-turn at Bang Sue station is changed to turn back through the turnout after Bang Sue station, but some trains reduce train speed for the previous train to depart from the time when the following train needs to use the same route. As a result, the trains must reduce speed which may affect other trains following.

It is recommended that mixed traffic on the main line operating in off peak periods have headway of Red Line trains at 15 minutes or 4 trains per hour (2 train each direction) to reduce the infrastructure load on the Taling Chan-Salaya section. In the case of a Red Line train (spur line) it is necessary to adjust the Red Line trains to be shuttle trains [instead], so that the spur line will have a terminus at Taling Chan. Shuttle trains may result in passengers having to change trains at Taling Chan Station, but this will result in fewer additional runtimes. Using a shuttle train will reduce the number of trains that require services on the route.

In the Red Line route, if the recommended frequency to operate intercity trains with Red Line trains (RL1, LD and F) during off-peak periods have headway of 15 minutes, during peak periods only Red Line trains (RL1 with RL2) at the headway 7.30 minutes can be mixed. They will use the U-turn through the turnout after the station to reduce the number of trains using the route.

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