At Which Station the Low-speed Train Should Be shunted into the Subsidiary Main Track on the Mixed Traffic Line?

Hag-Lae RHO [a]

[a] *Green Transport & Logistics Institute, Korea Railroad Research Institute, Uiwang, 437-757, Korea; E-mail: hlrho@krri.re.kr*

Abstract: A subsidiary main track for passenger station is a low-speed track section distinct from a through route such as a main track. It is parallel to a through track and connected to it at both ends by switches. It allows for fast, high priority trains to pass slower or lower priority trains going the same direction. In this paper we first describe the minimum headway between trains using the concept of blocking time in a block section, which depends on block systems, signaling system and safety technology. And then a stepwise process is presented to select a location, at which it is suitable to shun a low-speed train into the subsidiary track for a given train-traffic pattern. This process is tested using train traffic simulation program RailSys® with sample track data, which are surveyed from track geometry based on the to-be constructed line.

Keywords: Subsidiary Main Track, Minimum Headway, Blocking Time Stairway, Conflict

1. INTRODUCTION

A subsidiary main track for passenger station is a low-speed track section distinct from a through route such as a main track. It is parallel to a through track and connected to it at both ends by switches. It allows for fast, high priority trains to pass slower or lower priority trains going the same direction. If station arrival time interval between two successive trains is within the minimum headway by safety operation rule, the subsidiary main track should be installed in that station, so that the low-speed local trains can let high-speed express trains pass. It is one of the important rail-facilities for efficiency to order and organize the flow of rail traffic.

In this paper we first describe the minimum headway between trains using the concept of block occupancy time in a block section, which depends on block systems, signaling system and safety technology. With the blocking time stairway, we find that it is possible to determine the minimum headway between two successive trains. In this case blocking time stairway would touch each other with any tolerance in at least one block section. And then a stepwise process is presented to select a location, at which it is suitable to shun a local train into the subsidiary track for a given train-traffic pattern. This process is tested using train traffic simulation program RailSys® with sample track data, which are obtained from the to-be-constructed line Pangyo-Yeoju track geometry.

2. ESTABLISHMENT OF THE MINIMUM HEADWAY

2.1 Block Occupancy Time of Block Section

Why can't trains operate immediately behind another train as cars follow another car on the road? The answer to this question is very simple. This operation can be achieved if all trains on the track operate at the same speed and in the same stopping patterns. That's because fundamental safety problems exist in the railroads. Motorists can brake cars relatively quickly, but locomotive drivers require significant braking distance to brake trains to a stop. Since the friction coefficient that acts between wheels and tracks is small, train weight serves as a crucial factor in which railway vehicles require a longer braking distance. In addition, train passengers may take on the same risk like as passengers of cars who suffer severe injuries according to the effect of "inertia of the body" resulting from a strong braking force.

Due to differences in the physical characteristics, road traffic is referred to as "drive by visual interval", and railway transportation as "drive by space interval". In this connection, the railroad track is divided into block section, and one block section represents the track section whose boundary is set by two main block signals. From a safety standpoint, the basic principle of train operation is that only one train operates within the block section. To inform locomotive drivers that the block section where the train is to enter is empty, the signal status which main signal displays is shown through pre-signal. Accordingly, the travel time and distance between pre-signal and main signal as well as the distance and travel time between main signal and next main signal becomes a very important element in the train separation control according to train following relationship. Figure 1 shows time components of block occupancy time, which lasts from the time the movement authority is issued for one train to move towards the block section until another train is likely to receive movement authority to enter the same block section. Therefore, the occupancy time of the block section between main signal 1 and main signal 2 in the figure 1 becomes usually much longer than the time that trains occupy the block section.

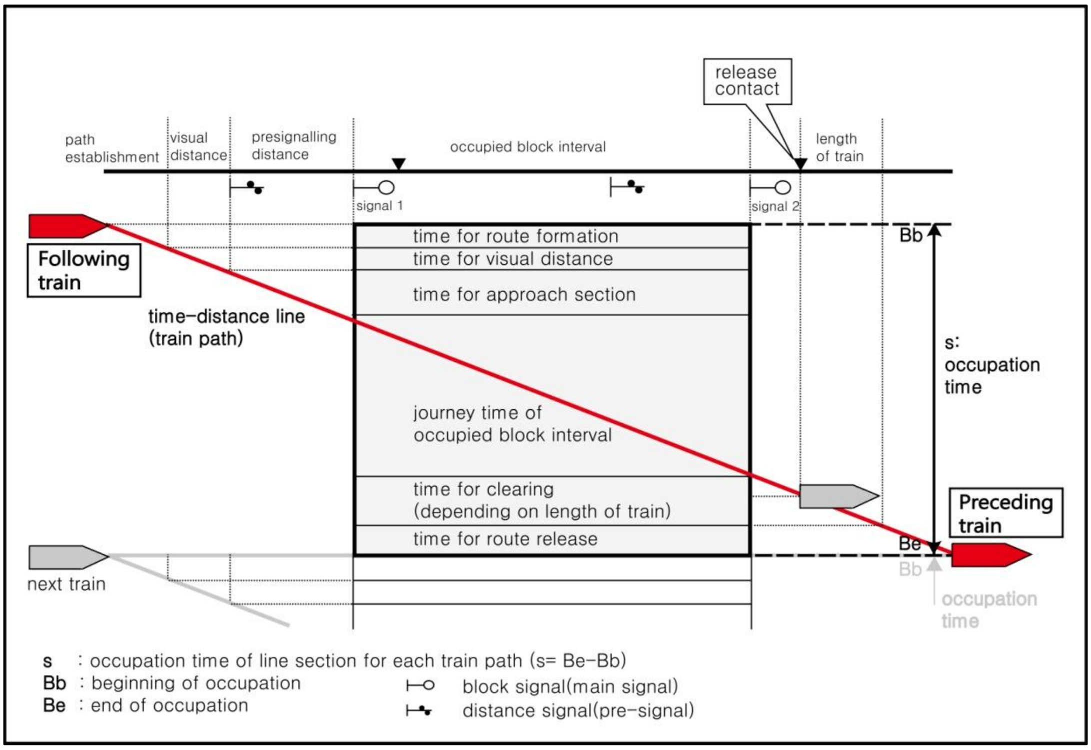

Figure 1. Blocking time of a block section in reference UIC (2004) p.13

2.2 Establishment of the Minimum Train Headway

The most important factor in train operation is to ensure safety. That is, the maximum limit of the railway transport capacity is limited by the element of ensuring safety. The train operation aims to maximize the transport capacity of the railway with safety and accuracy by minimizing the service interval between trains. In this case, the time interval between trains that can secure safety from the time one train passes through certain point until the next train passes through the same point is called the “headway” of train operation. In other words, the train headway means the time interval between the two trains that depart from, arrive at or pass through the certain point of main lines or stops, and it is the time interval required for the conflict-free train operation.

Meanwhile, the minimum headway means that the operation interval between two successive trains is minimized throughout certain line section, on which the train operating sequence should not be changed (for example by an overtaking). Therefore the minimum headway is to determine service interval of following train according to operational situations of preceding train. In this case, the minimum headway is calculated on the assumption that following train operates by green signals without deceleration for interval control [2].

The train headway is based on the operational situations of two trains at a certain point. The block occupancy time of all block sections is represented as blocking time stairway, and the minimum headway of the two preceding/following trains can be determined using the blocking time stairway. As shown in the Figure 2, the block occupancy time represents signal headway as the minimum headway between two trains within the block section. On the other hand, line headway is the minimum operating interval between two trains in consideration of the blocking time stairway of the entire line section, not only one block section. In this case, the blocking time stairway of two trains will stick to each other without a gap within at least one block section.

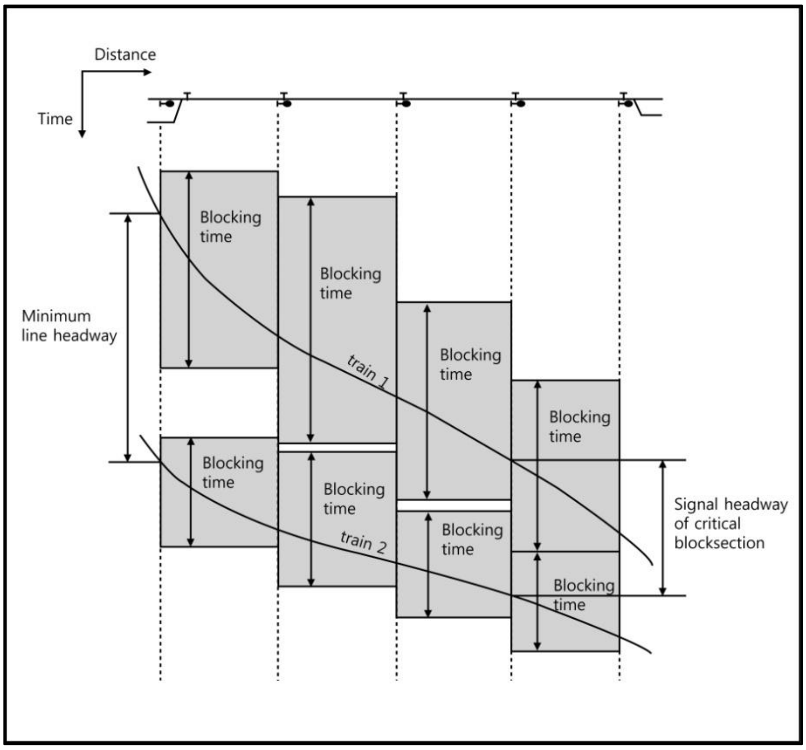

Figure 2. Blocking time stairway and signal and line headway in reference Pachl (2002) p.49

Meanwhile, in case two trains stop at intermediate station of the line section as shown in Figure 3, the block section in which the immediate stop is included becomes the critical block section that determines the minimum headway. That’s because the dwell time at the stop is included in the block occupancy time of the block section.

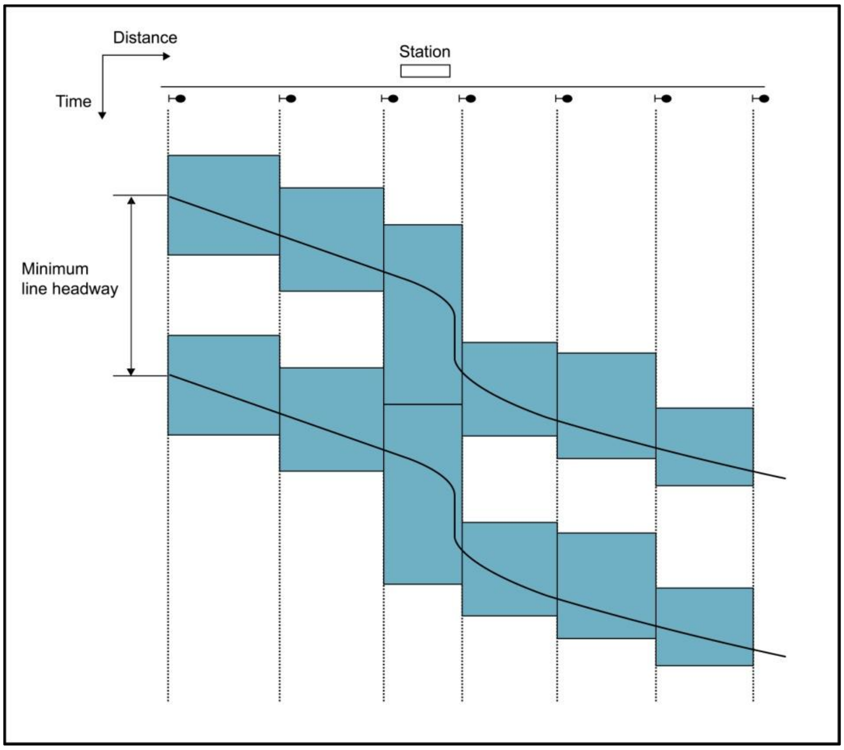

Figure 3. Line headway on a line section with a station in reference Pachl (2002) p.50

3. PROCESS OF SELECTING STATION FOR INSTALLATION OF SUBSIDIARY MAIN TRACK

As a track designed to shunt slow trains to allow express trains to overtake them on the mixed traffic line section, subsidiary main track is one of the important railway facilities for adjusting the flow of the train traffic efficiently. In case a high-speed express train operates behind a low-speed local train, the train operation should be made to meet the minimum arrival headway of two successive trains in the last block section of the line as long as the train sequence is not changed at the intermediate station. In this case, the headway at the start of the line should be large enough to avoid interference between following express train and preceding local train in the middle of the line section. However, as the headway becomes larger, train service interval increases, and the number of train operation decreases, which leads to lowering the quality of the train service. Accordingly, there is a need for changing the order of train operation in the middle of the line, in order to increase the quality of passenger service and train operation.

To run the preceding slow train and following express train together without conflicts, it is required for following express train to overtake the preceding local train at the intermediate station as shown in the following Figure 4. Figure 4 shows the situation where low-speed train 1 is followed by high-speed train 2 on the sing track. The fact that the width of block occupancy time of train 2 is narrow, and the slope of train operation line is gentle indicates that the speed of train 2 is higher than that of train 1. Although there exists buffer time between paths of the two trains, it is not enough to eliminate the conflict between the two trains. So, train 1 is shunted to the subsidiary main track of station B, then train 2 passes through the main track, thereby overtaking train 1.

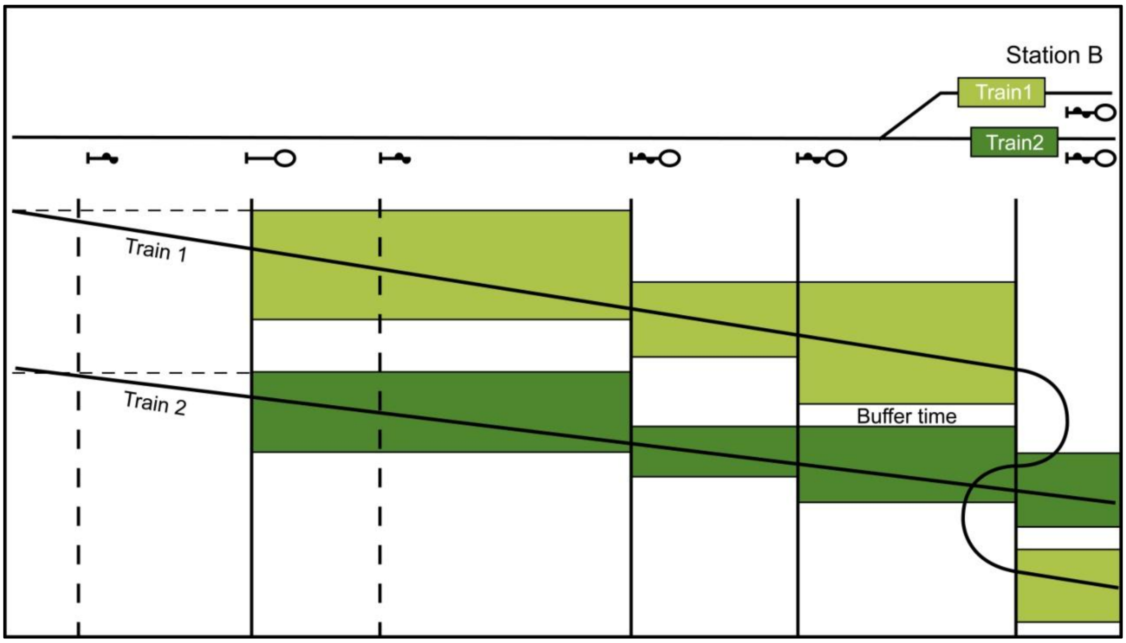

Figure 4. Overtaking local train 1 by express train 2 in reference Heister et al. (2009) p.268

Thus, the subsidiary main track should be installed in the station where disruption in train safety is anticipated, due to the fact that the difference of station arrival time between slow train and express train is within the minimum train headway. In this paper, the station in which the subsidiary main track needs to be installed on the mixed traffic line was selected through the flowing process.

1) Step 1: Calculation of running time between stops according to train service pattern (High-speed express or low-speed local train)

The minimum running time based on the main track operation is calculated in accordance with track alignment characteristics (gradients, curves, track top speed, etc.) and performance characteristics of service trains (vehicles). And to make up for the delay that occurs during train operation or have enough time for the brake-handling in case of station entry/exit, the operation time is estimated by adding a certain percentage of recovery time to the minimum running time.

2) Step 2: Calculation of basic headway based on departure station of express/local trains, considering passenger travel demand of the route

3) Step 3: Identification of conflict points between trains based on the basic headway and review on the resolution methods (see Figure 5)

Sequential review on the train headway of two trains is conducted from the departure station, in case preceding and following trains depart from the station of origin with the basic headway. Methods to resolve conflict is applied after figuring out point that causes conflict between trains.

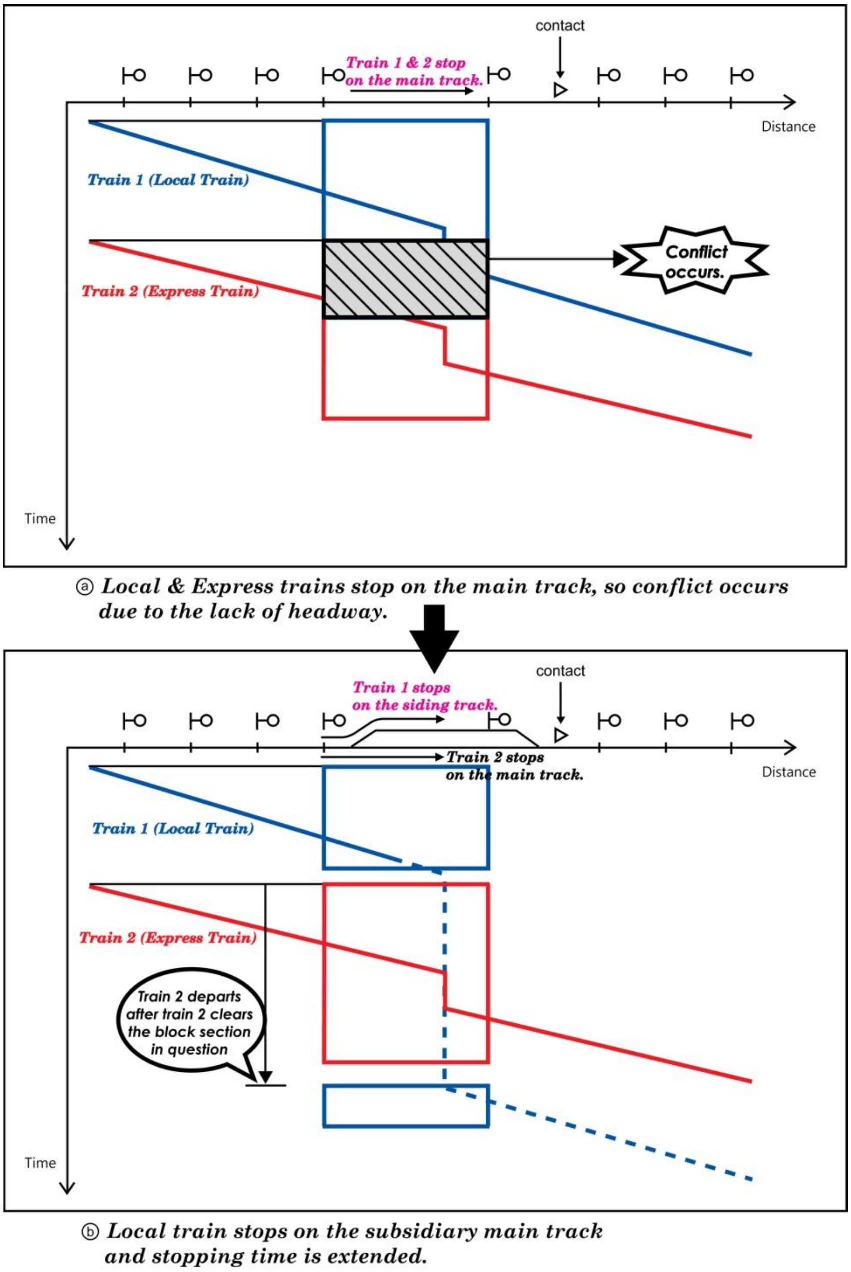

Figure 5. Plans for train operation due to the occurrence of conflict between preceding local /following express trains

4) Step 4: Extended dwell time of preceding local train according to the changes in the train sequence is calculated. Then the departure time of low-speed local train and high-speed express train at the train sequenced changed station is determined.

5) Step 5: After identifying the resulted train sequence from Step 4, the occurrence of conflict between trains in the line section after that station is reviewed as shown in Step 3.

6) Step 6: This process is implemented repeatedly until the final station of the train or last station of the line, and the point (station) at which conflict between trains occurs becomes the target location for installation of a subsidiary main track.

4. CASE STUDY OF SELECTING STATION FOR INSTALLATION OF SUBSIDIARY MAIN TRACK

4.1 Line to be reviewed and Basic Assumptions

In this paper, a case study of Pangyo~Yeoju railway construction line was carried out using train traffic simulation program RailSys® for selecting a target station for installation of subsidiary main track to shunt low-speed train on the mixed operation track. The target line for review has the total length of 56.01km, and it is composed of 11 stations, including starting station and terminal station. It was assumed that only two kinds of passenger trains such as high-speed express train with the maximum running speed of 250km/h and low-speed local train of 120km/h operate on this line. As shown in Figure 6, a subsidiary main track is designed at 4 stations (Gwangju, Gonjiam, Icheon, and Bubal) in this line. This paper investigated which station is appropriate for low-speed train to shunt into subsidiary main track to let high-speed express train pass under given local/express train service patterns.

Meanwhile, according to results of the traffic demand analysis on this line in 2036, total 8 trains, including 5 local trains and 3 express trains, are required based on one-way operation at peak hours. Therefore, conflict between trains was examined, assuming that 8 trains depart with 7.5 minute intervals from the station of origin. For train operation, the train service patterns of (local 1, local 2, express 1), (local 3, local 4, express 2) and (local 5, express 3) were assumed, and 1 minute (60 seconds) and 0.5 minutes (30 seconds) was applied as dwell time at stops of express train and local train respectively. In addition, this process was based on the premise that the distance-to-go ATP system is operated in this line.

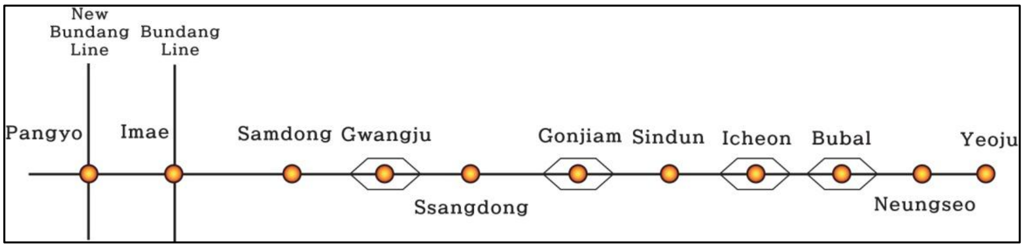

Figure 6. Routing and station plan of Pangyo~Yeoju line

4.2 Selection of Station for Installation of Subsidiary Main Track to Shunt Low-Speed Trains

1) Pangyo → Yeoju direction

In case eight trains depart from Pangyo station at headway of 7.5 minutes, conflict between local 2/express 1 trains, local 4/express 2 trains and local 5/express 3 trains occurs in Sindun→Icheon→Bubal section as shown in Figure 7. To resolve this problem, the departure time of local 2/local 4/local 5 trains needs to be delayed by 1 minute at Pangyo station. If the trains make a stop at the subsidiary main track of Gonjiam station, and the dwell time is extended from 30 seconds to 3 minutes and 30 seconds as shown in Figure 8, the problem of conflict between high-speed/low-speed trains can be resolved. In this case, high-speed express 1/express 2/express 3 trains depart earlier than preceding low-speed local trains do, after making a stop at the main track of Gonjigam station, where operation sequence of high-speed express train and low-speed slow train is changed.

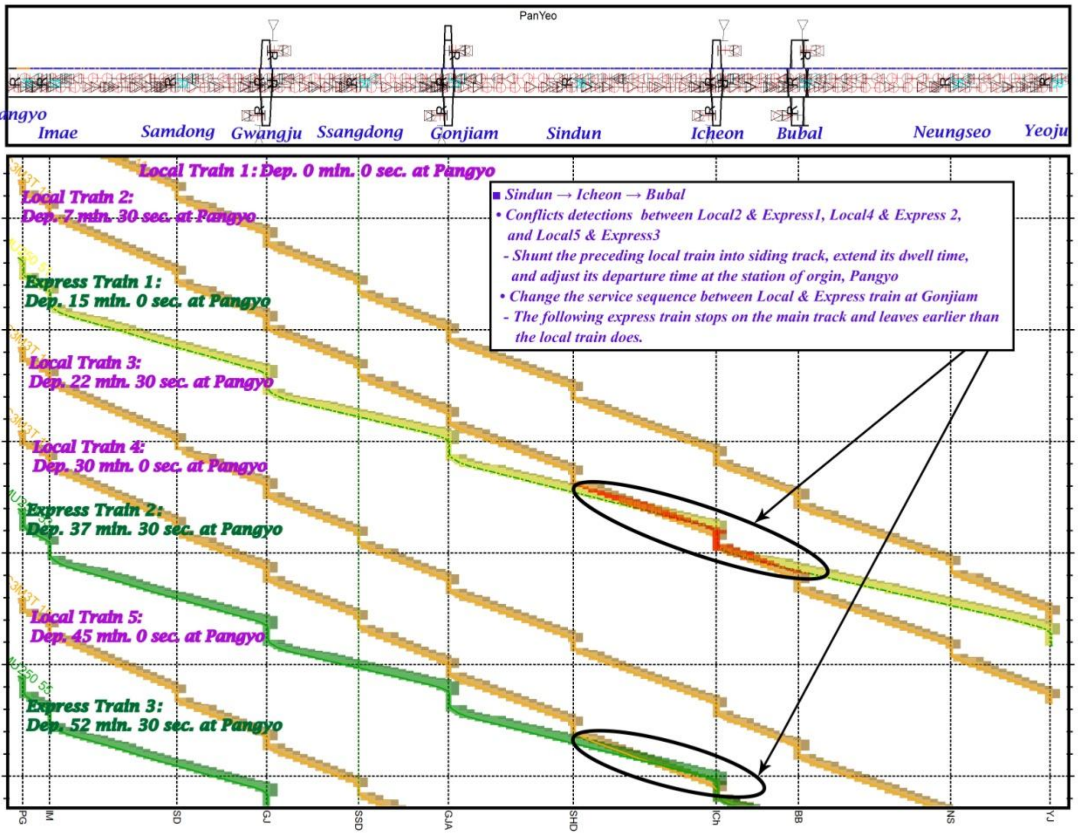

Figure 7. Conflicts detections on the Pangyo → Yeoju direction

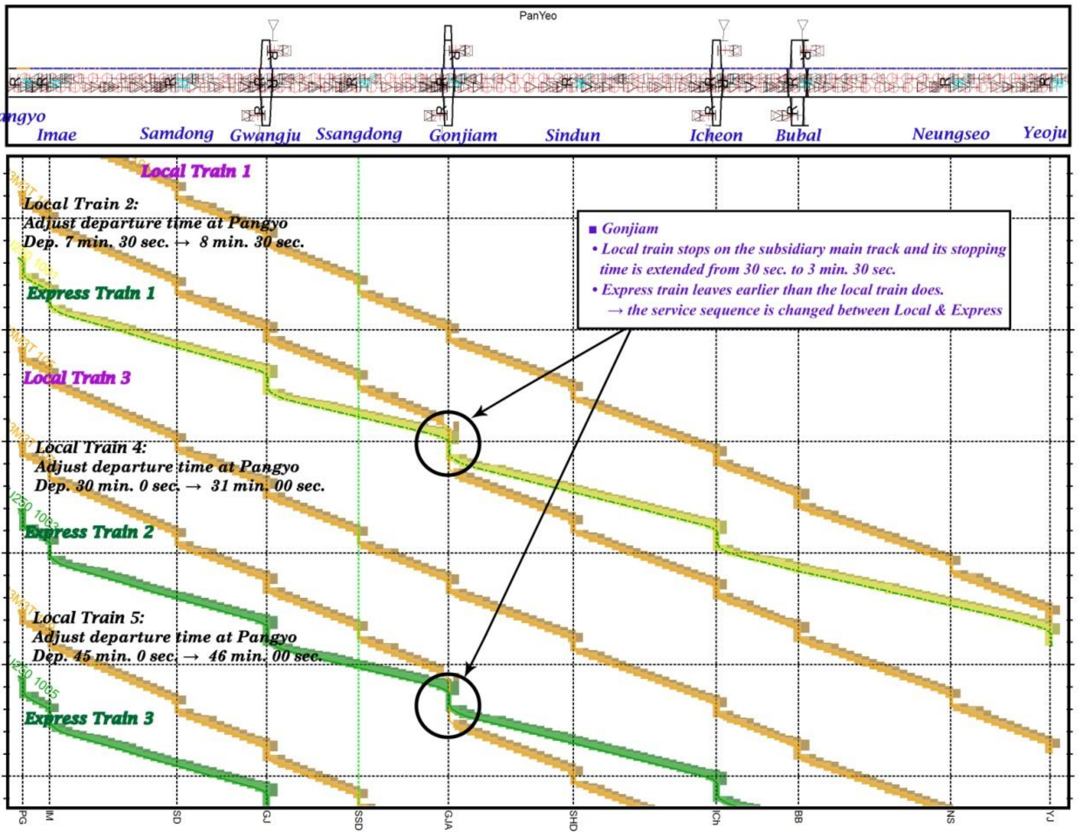

Figure 8. Conflicts resolution on the Pangyo → Yeoju direction

2) Yeoju → Pangyo direction

In case eight trains depart from Yeoju station at the headway of 7.5 minutes, conflict between local 2/express 1 trains, local 4/express 2 trains and local 5/express 3 trains occurs in Icheon→Sindun→Gonjiam section as shown in Figure 9. In addition, conflict between local 1/express 1 trains and local 3/express 3 trains occurs in Imae station. To resolve this problem, the departure time of express 1/express 2/ express 3 trains needs to be delayed by 2 minutes and 30 seconds in Yeoju station. In addition, if local 2/local 4/local 5 trains make a stop at the subsidiary main track of Gonjiam station, and the dwell time is extended from 30 seconds to 3 minutes and 30 seconds as shown in Figure 10, the conflict between high-speed/low-speed trains can be resolved. In this case, high-speed express 1/express 2/express 3 trains depart earlier than low-speed local trains do, after making a stop at the main track of Gonjigam station, where operation sequence of high-speed express train and low-speed local train is changed.

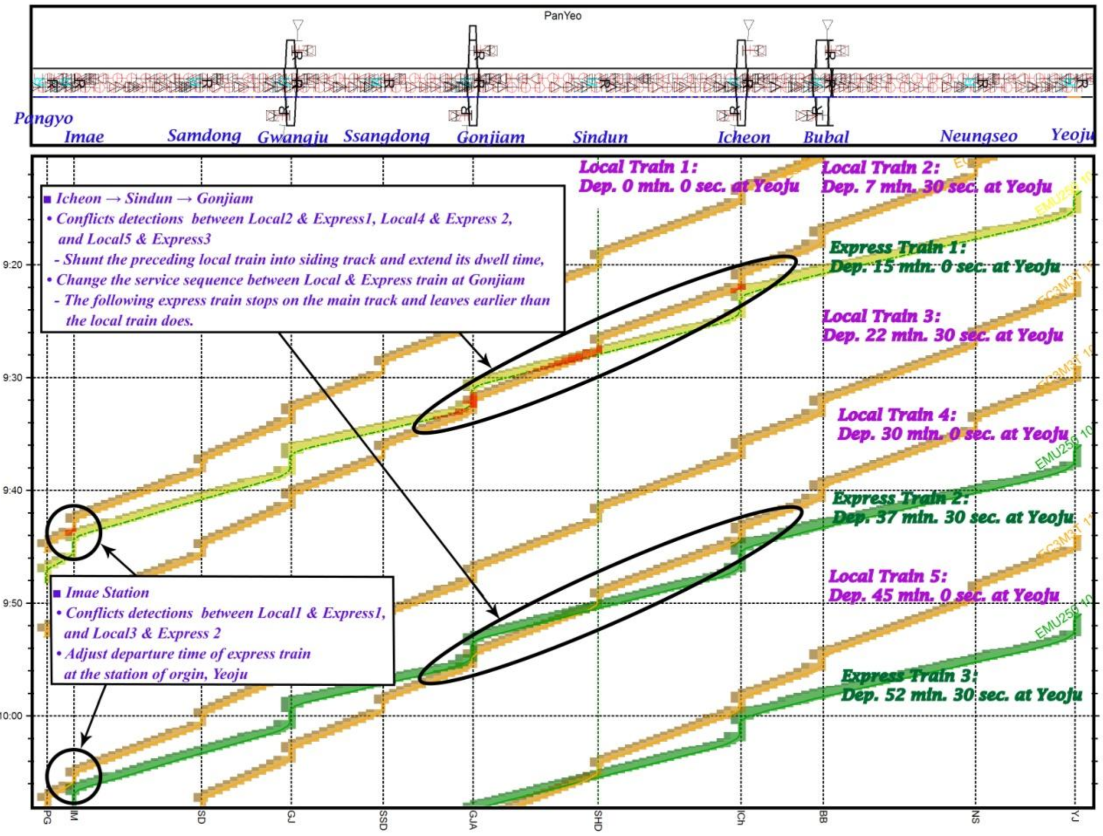

Figure 9. Conflicts detections on the Yeoju → Pangyo direction

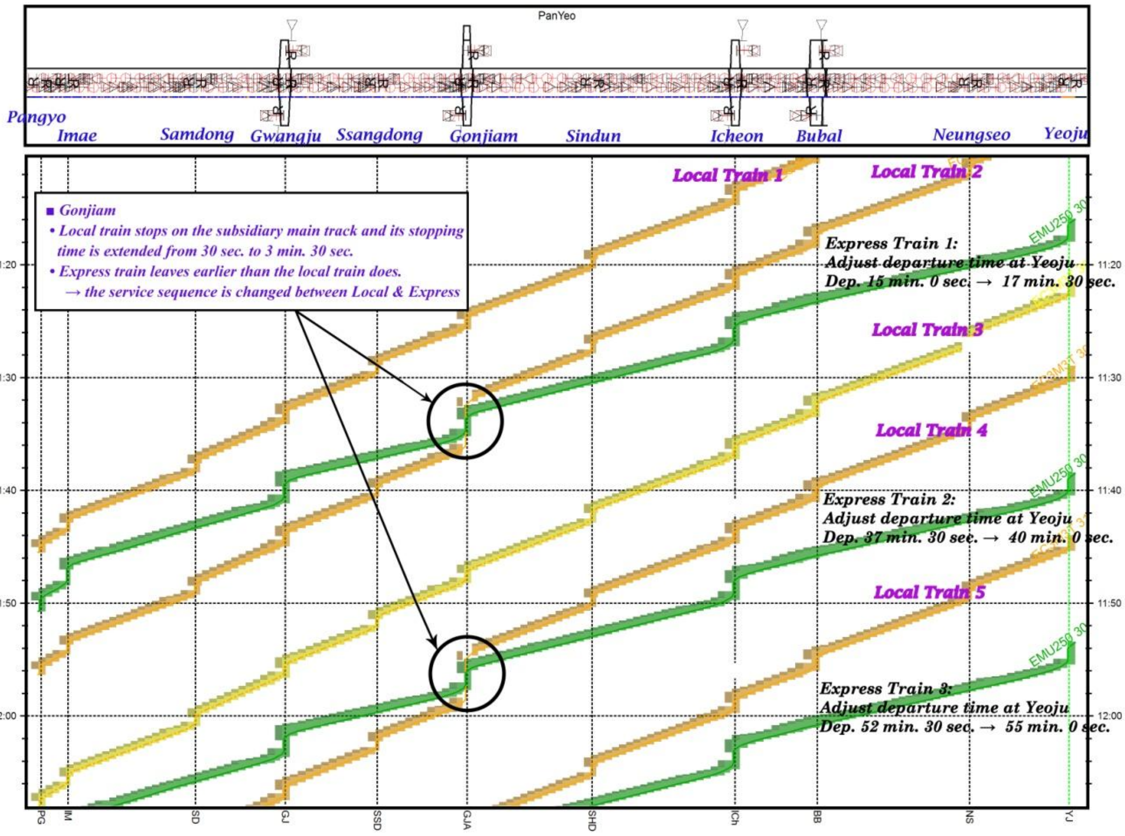

Figure 10. Conflicts resolution on the Yeoju → Pangyo direction

5. CONCLUSION AND FUTURE RESEARCH

To maintain the operation sequence of slow/express trains in the mixed traffic track without shunting low-speed local trains, the headway at the station of origin should be fairly large. However, as train service interval becomes large, the number of train operation decreases, resulting in ineffective use of the rail capacity. Accordingly, to reduce the headway in the mixed operation track, it is necessary to install subsidiary main track in the intermediate station so that preceding low-speed trains can let following high-speed trains pass.

In this paper, the concept of block occupancy time of trains and methods for calculating the minimum headway between two trains were investigated, and it was identified that conflict between trains can be resolved by adjusting the headway to ensure that the blocking time stairway of trains does not overlap each other. To verify these methods, the case study on the Pangyo~Yeoju railway construction line was carried out using train traffic simulation program RailSys® for selecting a target station for installation of subsidiary main track to shunt low-speed train on the mixed traffic track.

The simulated operation on the 5 low-speed local trains and 3 high-speed express trains with the headway of 7.5 minutes at peak hours was conducted, considering travel demand of this line in 2036. From its results, it was found that installation of subsidiary main track is needed at Gonjiam station. Meanwhile, since the review results of this paper is based on the premise that the train operates at the headway of 7.5 minutes, it should be taken into account that the target station for installation of a siding track can be subject to change due to modifications in operation pattern and occupancy time in case buffer time is applied in the train headway to prevent delayed transition between trains.

Therefore, it is required to conduct additional research on the methods to resolve conflict between trains by scenario, through reviewing various scenarios for train service pattern in the future. In addition, since this paper investigated the target station for installation of the subsidiary main track to shunt low-speed trains based on the given train traffic, additional research is needed to set the track dimension in the station, according to the function of the station and train operating purpose such as shunting vehicles and handling cargo.

REFERENCES

Heister, G. et al. (2009) *Eisenbahnbetriebstechnologie*. Bahn Fachverlag, Heidelberg – Mainz, Germany.

Kim, E. I. (1999) *Train Operation Theory*. KROTC, Seoul, Korea (in Korean)

Pachl, J. (2002) *Railway Operation and Control*. VTD Rail Publishing, Mountlake Terrace, USA.

UIC Leaflet 406. (2004) *Capacity*. UIC International Union of Railway, France.

Hansen, Ingo A. et al. (2008) *Railway timetable & Traffic*, Eurailpress, Hamburg, Germany

Hansen, Ingo A. et al. (2010) *Timetable Planning and Information Quality*, WIT Press, Southampton, UK