Shortening total trip time by short station dwell time and passing local trains

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Abstract

We are studying to shorten passengers’ total trip time to improve train diagram by operation of rapid trains. We calculate and deal with combinations of stations to shorten the time where rapid train stop or the train pass to local train. There are many combinations in this problem, and we have to consider any limit conditions. Therefore, we waste very long computation time to get the solution. To solve this problem, we adopted a following procedure using dynamic programming (DP), we could get a combination of the stations which has effectiveness. We have applied this method to metropolitan subway in Tokyo. We could get the evaluation value that we can expect to about 6% shorter trip time than the time of operation local train only. We may have better solution, however, it was shown the possibility to shorten the trip time by the rapid train. To shorten the time, this approach by improvement of train diagram has a merit not to need the equipment investment.

1 Introduction

We are studying to shorten passengers’ total trip time by operation of rapid train (Katori [1]), because this approach does not need to pay for investment (Iguchi [2]). This approach to shorten the time belong to improve the train diagram. There are many combinations of the stations where rapid trains stop or pass to local train. And there are many limit conditions to realize train diagram. In fact, it is impossible to solve this problem by round robin because we need explosion computation order.
In this paper, we describe about to solve the combinatorial problem in short time, in many combinations of stations where rapid train stops or passes to local train. This combination of the stations has effectiveness to operate rapid train. We are using a trend that the case of rapid train stops stations where have many numbers of passengers has effect.

This method to solve does not get an optimum solution because the stopping stations are determined static in order. However, we applied to real rail line, as a result, by proper setting rapid train stopping station or passing to local one, it was shown to shorten total trip time about 6[%] comparison operation of rapid train with local train only.

2 Conditions of operation of rapid train

2.1 Evaluation value

In this study, our aim is to shorten passengers’ total trip time. For the aim, we operate rapid train by setting proper stopping stations or passing to local train. A passenger can move shortest time if the rapid trains stop his getting on and off stations only. However, this combination of the stations has possibility that other passengers need longer moving time. We cannot satisfy to request by all of passengers, we need to calculate the combination to shorten total trip time of all passengers.

Therefore, our evaluation value is:

\[ E(\text{total trip time}) = \Sigma (\text{require time}) \times (\text{number of passengers}) \]

Require time = waiting time + moving time

Number of passengers means between any stations each other (from OD table).

The smaller evaluation value means good one.

The evaluation values are compared operation of rapid train with local train only, if

\[ E(\text{local train only}) > E(\text{operation of rapid train}) \]

it means that operation of rapid train has effect.

2.2 Assumption for operation of rapid train

In this study, we assume any conditions for operation of rapid train as following:

1) The kinds of trains are twice only (rapid and local train). The rapid trains’ stopping or passing to local train stations are static.

2) Railway line has double track. The rapid train can pass to local one at the station only (Figure 1).

3) We don’t operate the train that turns on part of the station.

4) The minimum gap time between trains is 2 minutes.

5) The passengers don’t spend especial fee to get on the rapid trains. They don’t have trade off for costs.

6) All passengers change to rapid train at the part of stations if they can shorten
their trip time.
We deal with two kinds of standard train diagrams. We call "departure cycle", it means the time between a rapid train and next rapid train starting at the first station, we can calculate minimum the time.

3 Procedure to calculate of the effect by rapid train

Figure 2 shows procedure to calculate of the effect by rapid train. About this procedure, at first, we set stations where rapid train stop or the train pass to local train. We use dynamic programming for determination of the stations where rapid train passes to local one. Second step, we judge possible or impossible to make train diagram. Next step, we make standard train diagram for the combination using moving time between any stations. In this step, we are setting a condition that the trains don’t turn on part of the stations. Last step, we calculate the passengers’ total trip time by OD table and the train diagram.
We repeat these steps for any combinations.

3.1 Calculation of total trip time for operation of local train only

We make train diagram for operation of local train only using conditions of application line (for example, moving time between stations, equipment to pass each other trains at the station). We calculate the passengers’ total trip time (=evaluation value) by expression (1), using the train diagram and OD table. This evaluation value names "Total trip time (1)".

3.2 Calculation of total trip time for operation of rapid train

We have to set the stations where rapid train stops or passes to local train, to compare of total trip time with operation of local train only.

3.2.1 Determination of rapid train stopping stations
The rapid train stopping stations are determined in order the number of passengers because there is a tend that the case of rapid train stops stations where have many numbers of passengers has effect. Therefore, we may not get an optimum solution.
3.2.2 Setting for rapid train passing to local train

We determine the stations where rapid train passes to local train and the number of the stations. For this part, we use the thinking way of dynamic programming.
3.2.3 Judgment of possible or impossible to make train diagram
We judge possibility to make train diagram by combination of the stations where rapid train stop or pass to local train. For example, it is impossible to make train diagram if there are continuous the stations where rapid train passes to local one.

3.2.4 Making train diagram for these stations
We make simple standard train diagram using moving time between any neighbor stations. The diagram, it is possible to make some diagrams in same stations where rapid trains stop or pass to local one. In this paper, we make two train diagrams both the number of rapid train and local one is equal or not equal (Figure 3), and we compare effect of operation that the number is equal with not equal. In this step, we are setting a condition that the trains don't turn on part of the stations.

(1) The case of equal number of rapid train and local train (rapid : local = 1 : 1)
This case means that rapid train and local train starts one after the other. We calculate minimum departure cycle time during first rapid train to second rapid train. The minimum cycle time is determined by the number of passing stations between each stations where rapid train passes to local one.
We make a train diagram in equal number of rapid and local one. At first, we draw rapid train’s diagram in the condition of the stations, the after, we draw local train's diagram that the train arrives a terminal station before two minutes of the rapid train arriving.

(2) The case of not equal number of rapid train and local train (rapid : local=1 : n)
The ratio between rapid and local trains is determined by the number of rapid train passing to local trains. Namely, a local train is passed once only by rapid train. We draw rapid train’s diagram. The after, we draw local trains’ diagram from the station where the train is passed by rapid train.

Figure 3: Example of making train diagrams.
3.2.5 Calculation of total trip time included operation of rapid train

We calculate passengers' total trip time using OD data and made train diagrams. The train diagram expresses graph data. On train diagram, nodes are points of the trains stopping station, links are lines connected each stopping stations and have weight of time. At a time and at a station, we search trip time to other stations by graph algorithm of dijkstra’s shortest path (Dijkstra [3]). We calculate total trip time by integrated these trip time and OD data for any combinations between the time, starting stations and destination stations. This evaluation value is named "Total trip time (2)". If

\[ "\text{Total trip time (1)}" > "\text{Total trip time (2)}" \] (3)

then the combination has effect to operate rapid trains.

We calculate the total trip time both the number is equal and not equal, compare with the effects.

We repeat these procedures, and search the combination of the stations that has higher effect to operate rapid trains.

4 Applied sample and discussion

We show an applied sample and result of evaluation value for a real line, in this section. We have applied subway Tozai line through to Toyo Rapid line, these lines' total length are about 47km, and the lines are running through center of Tokyo. Total number of stations are 30, the track to pass rapid train to local train are equipped at 6 stations now (Figure 4). OD date of passengers are used by reference No.[4].

We have made two case of train diagrams both number of rapid : local = 1:1 and rapid : local=1:n. The parameters are as following

1. Real passing equipments are considered or not considered

Figure 4: An application line (Subway Tozai line to Toyo rapid line).
(2) Departure cycle time of rapid trains is equal in daytime (15 minutes) or possible to short (7 minutes).

We have gotten the combinations that have high effect to operate of rapid train, and have gotten two evaluation values (total trip time), included rapid train and local trains only.

Table 1 shows result of ratio of these evaluation values. Figure 5 shows the combination of stations which has shortest evaluation values by the procedure.

<table>
<thead>
<tr>
<th>Trains ratio rapid : locals</th>
<th>Departure cycle time [minutes]</th>
<th>Passing equipment</th>
<th>Ratio of evaluation values Included rapid / local only</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 : 1</td>
<td>7</td>
<td>all stations</td>
<td>0.95</td>
</tr>
<tr>
<td>1 : 1</td>
<td>11</td>
<td>real stations</td>
<td>0.98</td>
</tr>
<tr>
<td>1 : 1</td>
<td>15 (=now)</td>
<td>all stations</td>
<td>0.97</td>
</tr>
<tr>
<td>1 : 1</td>
<td>15 (=now)</td>
<td>real stations</td>
<td>0.99</td>
</tr>
<tr>
<td>1 : 3 (1:n)</td>
<td>23</td>
<td>all stations</td>
<td>0.95</td>
</tr>
<tr>
<td>1 : 1 (1:n)</td>
<td>17</td>
<td>real stations</td>
<td>0.99</td>
</tr>
<tr>
<td>1 : 1 (1:n)</td>
<td>15 (=now)</td>
<td>all stations</td>
<td>0.94</td>
</tr>
<tr>
<td>1 : 1 (1:n)</td>
<td>15 (=now)</td>
<td>real stations</td>
<td>0.99</td>
</tr>
</tbody>
</table>

Table 1 shows that it is possible to expect to shorten total trip time about 5[%] by the ratio of 1:1, or about 6[%] by the ratio of 1:n. However, there may be solve of the combination which have shorter total trip time because the rapid train stopping stations were determined in order the number of passengers. In the case of these lines, 1:n of the ratio have tend of higher effect to shorten total trip time than the case of 1:1 ratio.

The relation of the number of the ratio, effect to shorten the time and position of proper stations where rapid train pass to local one, are determined by balance in OD table. We have to detail consider of these relations in future.

The order of computation time is \(O(n^3)\) by this procedure. Therefore, we could get the solution in practical computation time (about 20 minutes by 550[MHz] PC). If we use the method of round robin for this problem, The order is \(O(4^n)\), we will not be able to get the solution until next correction of train diagram, by the same PC.
5 Conclusion

To improve railway transport system, we have described to shorten passengers’ total trip time by operation of rapid train. We had compared the total trip time with any combinations of the stations each other where a rapid train is stopping or passing to local train. We have taken the combination that has effect to shorten the time.

There are many combinations in this problem. To shorten computation time, we used thinking way of dynamic programming to solve the combination of stations where rapid train passing to local one. However, we have determined the rapid train stopping stations in order the number of passengers, we might not get an optimum solution. It may be exist an optimum solution in other combinations. We have made two train diagrams under the condition that the trains don’t turn on part of the stations. We have applied this procedure real subway line in Tokyo, we could get solutions of the combinations to shorten the time about 6[%] in practical computation time.

In future, we will consider the relation between OD and stations where rapid train
pass to the local one, how to take an optimum combination in practical computation time.

Reference


