Computers in Railways VII, C.A. Brebbia J.Allan, R.J. Hill, G. Sciutto & S. Sone (Editors)


# Rail service on triple-track lines: proposal and benefits

K. Katsuta[1], T. Koseki[1] & S. Sone[2]
[1]*Department of Electrical Engineering, School of Engineering, The University of Tokyo, Japan.*
[2]*Department of Electrical Engineering, Kogakuin University, Japan.*

## Abstract

Commuters who go to schools and offices in the morning congest trains, and this has been a serious social problem in Japan. On the other hand, the cost to purchase land for a new track is very high. The authors, therefore, propose an efficient railway operation by using a triple-track line, which has the large flexibility and provides services much better than a double-track line, as well as not much worse than a quadruple-track line, with novel train scheduling adapting demand structure. The significance of the railway service on a triple-track line has been verified based on the calculations of waiting time, boarding time of passengers, and costs of facilities for the operations.

## 1 Introduction

The population density in Japan is very high in the metropolitan area. There is a time zone, which is called "the commuter rush hour". People who commute in the morning always congest trains, and this has been a serious social problem. Although many railway operators were going to improve their railway service, few works have been done, because an improvement of the railway service usually needs the extension of railway infrastructure, which will result in enormous cost in urban area. On the other hand, the service in a small space causes many restrictions in the train scheduling.

Computers in Railways VII, C.A. Brebbia J.Allan, R.J. Hill, G. Sciutto & S. Sone (Editors)




# 2 Problems and proposal

## 2.1 Problems of a double-track line

First of all, we have to consider the restrictions of the railway service on a double-track line. As figure 1 indicates, this operation causes operating density limits or slowdown of the express trains. On this account, many city-to-suburb lines sacrifice their own rapidity in Japan.

## 2.2 Problems of a quadruple-track line

A quadruple-track line enables the both highly dense and rapid train operation. Since one track can be exclusively used by local trains, while the other is used by express trains. It is, however, often a too expensive solution, because land purchase, where there are many commuters, costs enormous investment, while the population, *i.e.*, the traffic demand: in Japan subtly decreases. In fact the quadruple-track line is only 1.5% of all lines in the metropolitan area.

## 2.3 Proposal of a triple-track line

Judging from the above, we propose a railway service on a triple-track line, as an intermediate and rational solution: Railway operators can provide the service not much worse than on a quadruple-track line, adjusting a transport capacity and rapidity flexibly according to a demand structure.

# 3 Characteristics of the proposed operations on a triple-track line

## 3.1 Model line and relative variables

We will discuss eight significant characteristics of the proposed operation on a triple-track line in a city line, which has "commuter rush" problem. We set distance between stations to 2-3 km, namely required time between stations to 1-2 minutes, and one big station per six stations in the model line; illustrated in figure 2.

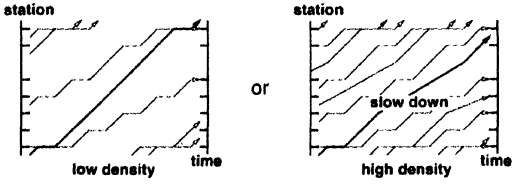


Figure 1: Restrictions on a double-track line.

Computers in Railways VII, C.A. Brebbia J.Allan, R.J. Hill, G. Sciutto & S. Sone (Editors)




In such a line, it seems reasonable to suppose that the passenger riding between three stations and riding between two big stations are representative of passengers riding short and long distance, respectively; illustrated in figure 2.

We propose the following eight train operations and indicate their efficiency, therefore, the service level of the model line will be evaluated by the five following relative variables normalized by the case of the double track line; illustrated in figure 3. And it will be compared with effects of the quadruple-track line; illustrated in figure 4. We will show these at section 3.10. In that section, we set relative variables based on required time, transport capacity, and operating costs, which are mainly important in the railway service.

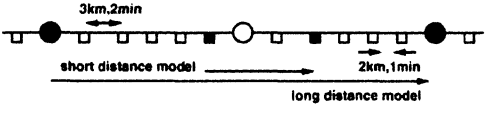


Figure 2: Model line.

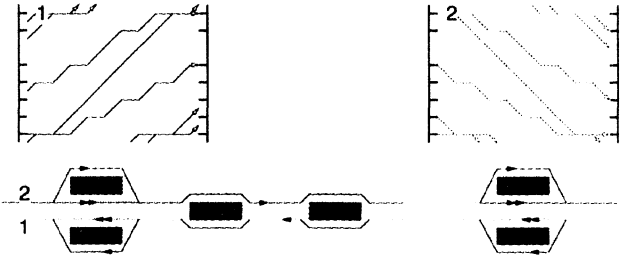


Figure 3: Scheduling and structure of a double-track line.

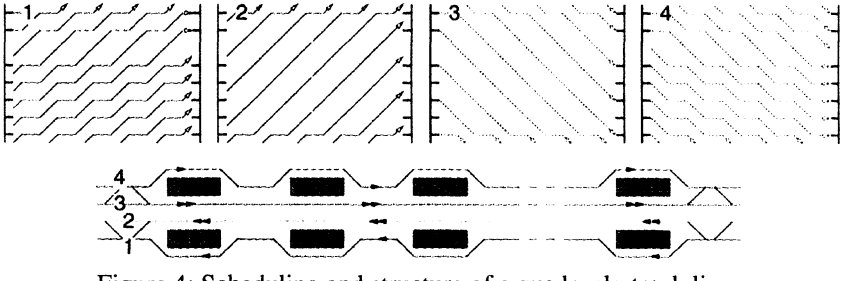


Figure 4: Scheduling and structure of a quadruple-track line.

Computers in Railways VII, C.A. Brebbia J.Allan, R.J. Hill, G. Sciutto & S. Sone (Editors)




### 3.2 Operation of frequent express trains with local trains

As figure 5 indicates, it is possible to operate the express trains frequently by using the center track for the operation of local trains in both directions. This way is suitable for intercity lines.

### 3.3 Operation of the frequent local trains with the express trains

As figure 6 indicates, to use the center track as the express trains passing the local trains in both directions, it is possible to lose passed loss time of the local trains [1] and to operate the local trains frequently with the express trains. This way is suitable for city-inside lines.

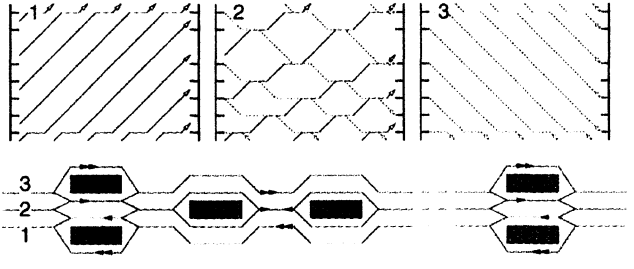


Figure 5: Operation of frequent express trains with local trains.

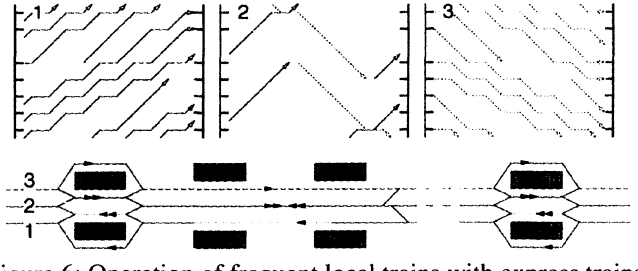


Figure 6: Operation of frequent local trains with express trains.

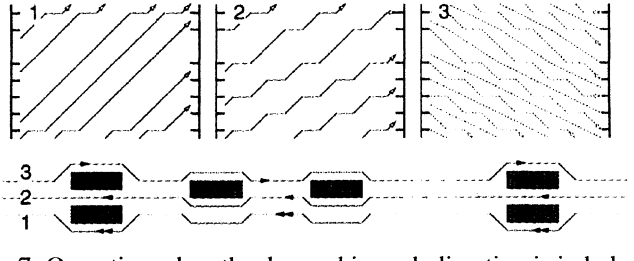


Figure 7: Operation when the demand in each direction is imbalanced.

Computers in Railways VII, C.A. Brebbia J.Allan, R.J. Hill, G. Sciutto & S. Sone (Editors)




### 3.4 Operation when the demand in each direction is imbalanced

As figure 7 indicates, in case that the demand is imbalanced in one direction, to use two tracks as operation of the trains in this direction, it is possible to obtain a large transport capacity and rapidity in this direction, although the service in the other direction becomes bad. This way is suitable for very crowd lines going to the metropolitan area.

### 3.5 Operation of supplemental trains at zonal separation scheduling

In case that a very big amount of passengers go to the terminal station from others rather than between middle stations, the local-separate scheduling is effective and used. As figure 8 indicates, on the triple-track line it is possible to operate the express and local trains frequently and the supplemental trains, which were devised recently to improve railway service on a quadruple-track line and were impossible to run on a double-track line [2].

### 3.6 Operation for a large transport capacity and rapidity temporally

As figure 9 indicates, in the section that has garages at both ends, it is possible to obtain a large transport capacity and rapidity right after operating trains prepared at the garages before large demand occurs. This way is suitable when events are planned along the railway.

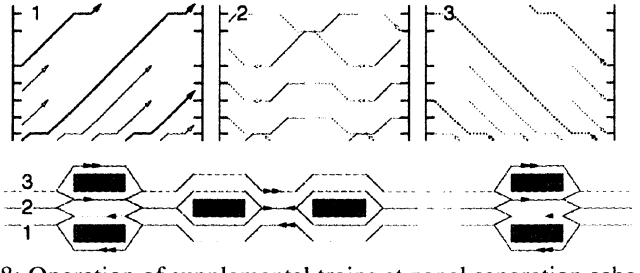


Figure 8: Operation of supplemental trains at zonal separation scheduling.

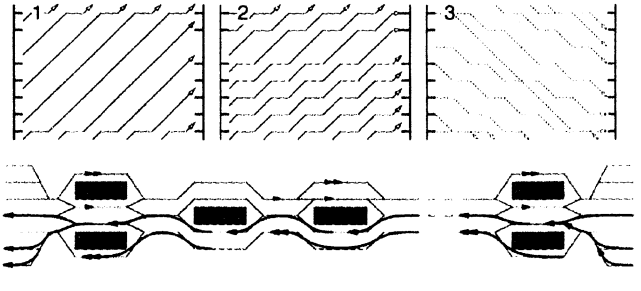


Figure 9: Operation for a large transport capacity and rapidity temporally.

Computers in Railways VII, C.A. Brebbia J.Allan, R.J. Hill, G. Sciutto & S. Sone (Editors)




### 3.7 Service robustness against delays

As figure 10 indicates, in case that one track is used in both directions, it would be untrue to say that delay happens and extends easily on the triple-track line. Even though an up train delays on the center track, a down train can run on time by using side track. We would like to emphasize that this is a different point from a single-track line.

### 3.8 Service robustness against accidents

If an accident happens, trains cannot run in both directions at this point on a double-track line, because they cannot return. But on the triple-track line as figure 11 indicates, an accident does not interrupt railway service, because they can run on the other two tracks in both directions.

### 3.9 Operation during maintenance and construction

The same may be said of the maintenance. The train operators can maintain one track daylong on the triple-track line, stopping this track like highways. It is easy to maintain and extend facilities on a large scale. We would like to emphasize that there are more useful points than the double-track line.

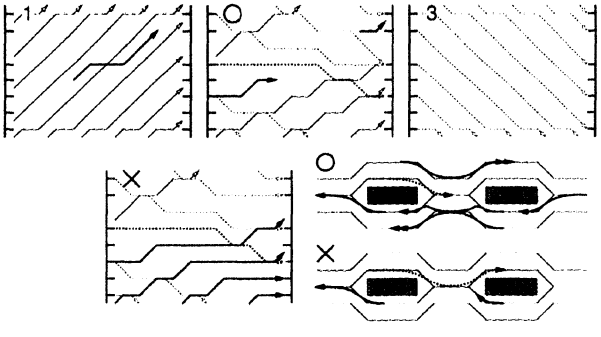


Figure 10: Service robustness against delays.

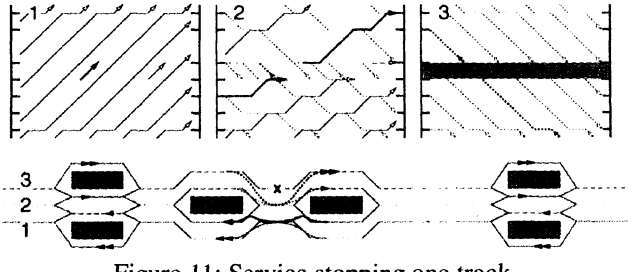


Figure 11: Service stopping one track.

Computers in Railways VII, C.A. Brebbia J.Allan, R.J. Hill, G. Sciutto & S. Sone (Editors)




### 3.10 Evaluation of the model line

Table 1 shows that the service level of the triple-track line is not much worse than the quadruple-track line for each short or long distance passenger. Therefore the service level of the triple-track line is not much worse than the quadruple-track line by the operation adjusted according to the demand structure.

Table 1: The evaluation in the model line.

| | Figure | RTSP | RTLP | TC | NT | LL |
|---|---|---|---|---|---|---|
| double-track | 3 | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% |
| triple-track | 5 | 82.6% | 86.5% | 244.8% | 207.7% | 151.5% |
| | 6 | 69.6% | 97.3% | 145.8% | 161.5% | 147.7% |
| | 7 | 69.6% | 87.6% | 174.8% | 261.5% | 145.5% |
| quadruple-track | 4 | 60.9% | 86.5% | 349.7% | 323.1% | 195.5% |

※ RTSP, RTLP, TC, NT and LL stand for the Required Time of a Short distance Passenger, the Required Time of a Long distance Passenger, the Transport Capacity, the number of Necessary Trains and the Line Length, respectively.

## 4 Discussion based on a case study of JR Keiyo Line

In this chapter, we show the results of calculations of effects based on the real line——JR Keiyo Line that links Tokyo and Soga (near Chiba). The amount written in figure 13 indicates the ratio of all passengers' loss time, normalized by the loss time on the double-track line, which includes waiting time at their origins and stopping time at middle stations, of each services in several cases. We compared them at the best train scheduling of each-track line, not changing basic preconditions *e.g.*, train speed, number of local stations, *etc.*

### 4.1 In the morning

We can recognize, from stopping loss time on the triple-track line as well as on the quadruple-track line in figure 13, that the triple-track line keeps rapidity. In addition, it is clear that a triple-track line has effect to relax congestion, according to figure 14.

### 4.2 During daytime

The proposed operation has no substantial advantage during daytime, since JR Keiyo Line has few stations and we cannot reduce stopping loss time at the

Computers in Railways VII, C.A. Brebbia J.Allan, R.J. Hill, G. Sciutto & S. Sone (Editors)




middle stations.

### 4.3 In the evening

The results in the evening have the same tendency as those obtained in the morning.

### 4.4 When a big event is held by the wayside

We can recognize, from loss time on the triple-track line as well as on the quadruple-track line, that a triple-track line has flexible measures against sudden large demand.

We take two examples of large and small events, which result in traffic demands. One is the case of a big concert of a very popular rock band, whose the amount of the audience is a hundred thousand. The other is the case of a baseball game, whose the amount of the audience is twenty thousand.

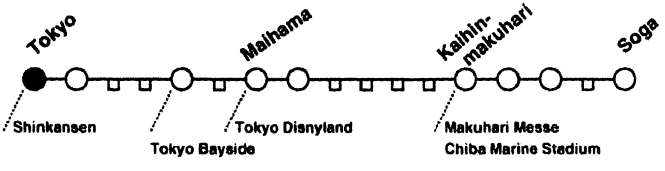


Figure 12: JR Keiyo Line.

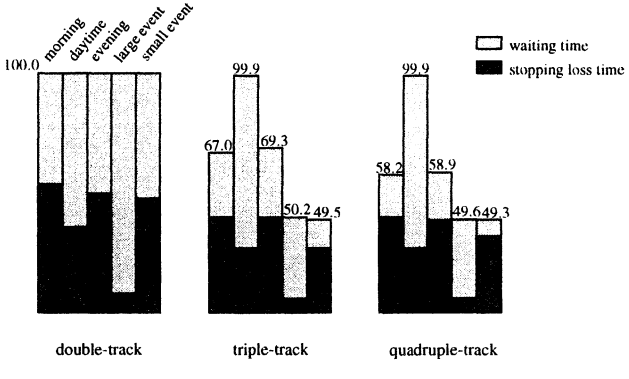


Figure 13: Loss times of services on each-track lines.

Computers in Railways VII, C.A. Brebbia J.Allan, R.J. Hill, G. Sciutto & S. Sone (Editors)



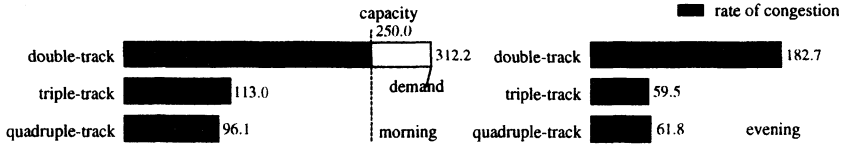


Figure 14: Maximum rates of congestion in the morning and evening.

### 4.5 Benefits and costs

It seems reasonable to suppose that the railway service on the triple-track line is more cost-effective than that on the quadruple-track line, by considering the following results of the comparison that indicate the extinction period of the triple-track line is shorter than the quadruple-track line.

Table 2: The comparison of the extinction periods.

| | Effects [min./day] | Benefits [$/day] | Costs to construct [$] | Extinction period |
|---|---|---|---|---|
| double-track → triple-track | 877287.5 | 519912.5 | 1.075 billion | 9.0 year |
| double-track → quadruple-track | 1146977.5 | 679740.6 | 2.150 billion | 13.8 year |

※ 1 day = morning (2h)+daytime (13.5h)+evening (4h).

※ 1 year = 250 weekdays.

※ 1 [min.] of loss time = $ 0.593 (= GNP [$/year]/ national working time[min./year]).

※ Costs to construct an overhead railway in Tokyo = 27.3 million [$/km] [3].

※ $ 1 = ¥110.

## 5 Conclusions

The railway service on the triple-track line is more effective than that on the double-track line, because of the following six substantial advantages:

I. Passed train needs no passed loss time.
II. Supplemental trains can be introduced into the zonal-separation scheduling.
III. You can reduce waiting and stopping loss times of both short and long distance passengers by adjusting the transport capacity and the rapidity according to the demand structure.
IV. You can have a large transport capacity and rapidity temporally if necessary.
V. The schedule is inherently robust against delays, failures and accidents.
VI. It is possible to maintain and inspect facilities for railway daylong and construct them on large scale.

Computers in Railways VII, C.A. Brebbia J.Allan, R.J. Hill, G. Sciutto & S. Sone (Editors)




On the other hand, it should be concluded that the railway service on the triple-track line is more cost-effective than that on the quadruple-track line at the following two substantial advantages:

I. The operation needs smaller space.
II. It is possible to construct and maintain facilities for the operation at smaller cost.

In addition, if our proposal is applied to a line, which was constructed or is planned as a double-track line, the railway will be more useful and it will lead to modal shift in urban area smoothly.

## 6 Future works

Only JR Keiyo Line, which has few stations, has been investigated quantitatively in this paper. Therefore we have to study furthermore the effects on several lines. For example, the lines have many stations or very large terminal station, run inside the city and so on.
It should also be added to compare benefits with costs more accurately.

It is considered that the next extensional step of a double-track is a quadruple-track in heavy rail systems, and the light rail systems tend not to use their own degrees of freedom in design. We expect that these things will be changing.

## References

[1] Toyota, N. & Sone, S. Improvement of Train Scheduling by Using a Triple-Track Line, National Convention Record, I.E.E. Japan, No. 680, pp. 6-173-174. 1991. (Written by Japanese.)
[2] Nishida, T. & Sone, S. Train Scheduling on a Quadruple-Track Line for Less Congestion, National Convention, Record, I.E.E. Japan, No. 227, pp. 4-1713-1714. 2000. (Written by Japanese.)
[3] Kameda, H. et al. New Railway System Engineering, Sankai-do, 1984.