A STUDY ON CHARACTERISTICS OF TRAIN STATION PASSENGERFLOWS FOR TRAIN DELAY REDUCTION

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ABSTRACT

In Tokyo Metropolitan Area, a railway network has been developed to reduce train congestion and impedance of transfers at stations through providing high frequency train operation. In addition, passengers have become able to ride other lines without transferring thanks to the introduction of inter-connected through service, which allows different railway companies to share lines. Unfortunately, negative impacts, notably train delay, are currently caused by the high frequency operation. The train delay is caused by not only the overcrowded train schedules but also the congestions at railway stations. In fact, passengers choose train doors in consideration of crowded condition at the platform as well as the structure of departure and/or arrival stations. An overconcentration to a door of a train often lengthens the dwell time of that train. This study focuses on the passenger flow at station and develops a simulation system to reproduce the complex passenger's walking behaviour taking into account the station facilities. Using this system, the paper describes the acquired knowledge that could be useful to the examination of measures to decreasing train delay.

Keywords: Urban Railway Planning, Train Delay, Passenger's Flow at Railway Station

1. INTRODUCTION

In Tokyo Metropolitan Area (hereinafter TMA), the railway network carries a large number of passengers everyday over a wide area with high speed, reliability, and safety. Service quality of this network has been improving constantly through the development of a high density railway network, using train consisting of many cars, operating at high-frequency intervals, sharing tracks between railway companies, introducing platform screen doors and so on. Today, the TMA's railway network is known as one of the world's leading transport systems in handling a huge traffic volume and securing reliable operation. Especially an overcrowded railway schedule and an inter-connected through service are key policies by Japan's railway to reduce congestion on the trains and provide the convenience to the passengers. As a result, Japan has obtained considerable effect through introducing these policies. However, these policies have also brought about undesirable effects, including (1) frequent occurrence of train delay during rush hours, (2) extension of the train delays to the wide area and (3) a long time required to get the delayed train system untangled. Almost daily congestion and train delay in the morning rush have caused intolerable pain to the passengers. It was reported that the total social costs by the train delays were estimated at over 200 billion yen per year (Kariyazaki, K and Iwakura, S (2009)).

The train delay is caused by not only the overcrowded train schedule but also the congestion at railway station. Passengers choose their train door in consideration of crowded condition at platform as well as structure of origin and/or destination station. An overconcentration to a train door lengthens the stopping time. It is possible to reduce the dwell time at railway station by controlling passenger flows at platform. Therefore, management of the passenger flows is one of the effective solutions to the train delay problem. This study focuses on the passenger's flow at the station and develops a simulation system which reproduces the complex passenger's walking behaviour taking into account the station facilities. Using this system, the paper describes the acquired knowledge of the examination of measures to reducing train delays.

2. PRESENT SITUATION OF TRAIN DELAYS

Because there is no statistical data on the short delays caused by congestion during rush hours, we cannot capture the actual state of the mechanism of worsening punctuality. Then, we have attempted to grasp occurrence state of the train delays using the sum of train delay certificates, which are issued by railway operators. As Tokyo Metro operates in the center of TMA and most of their lines share tracks with other railway companies, we calculated train delays by using the certificate issued by Tokyo Metro.In fact, Tokyo Metro issues a certificate for a train, which is delayed longer than 5 minutes, three times a day (morning rush, daytime, and evening rush). We collected the certificates for 8 months from 1 April, 2009 to 30 November, 2009.

2.1 Frequency of train delay occurrences

Figure-1 shows the number of the train delay certificate issued each day during a week. Tokyo Metro has operated 9 lines whose certificates issued about 13 times a weekday.Train delays in morning rush hours have contributed to 42% of the total number of certificates a day. For decreasing the number of commuters, the number of issued certificates during weekends is one third against the weekdays.

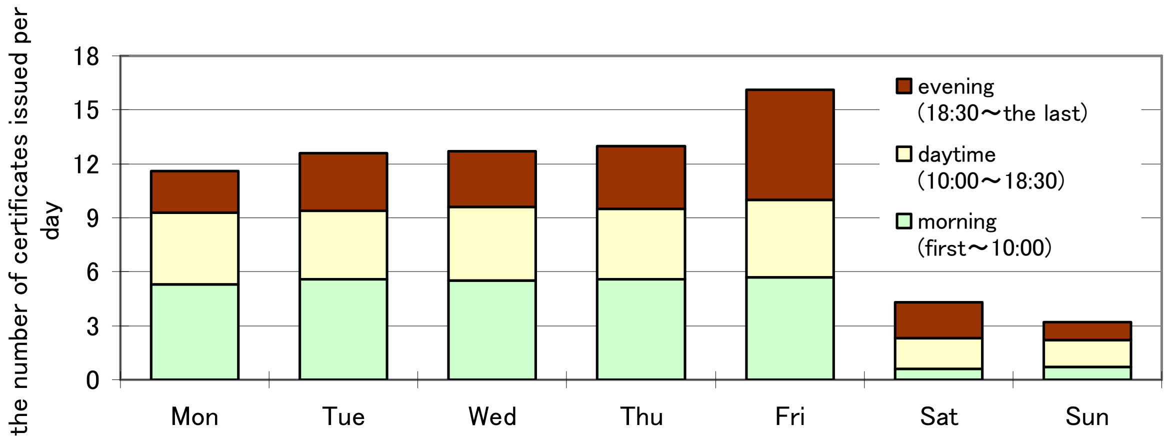


Figure 1 – The number of train delay certificate issued

2.2 Correlation between train delay and high-frequency interval operation

In Tokyo Metro, train operation at the minimum headway of 110 seconds is provided during peak hours. The correlation between the train delay and the train headway is shown in the Figure-2. The size of circle represents congestion rate of each line.It seems that the number of the certificates issued increase when train schedule gets more crowded. It seems difficult to secure the reliable operation at high-frequency intervals.

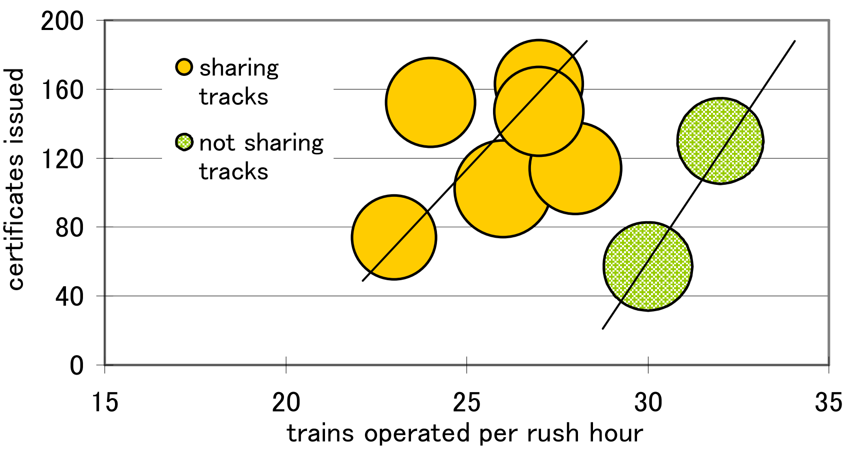


Figure 2 – the number of trains operated and the certificates issued

2.3 Influence of the inter-connected through service

There are 7 lines in Tokyo Metro which are sharing tracks between companies. Figure-3 shows the percentages of train delays of over 20 minutes among these lines. A portion of 46% of train delays is occurring in the shared tracks of other companies. It appears that the influence of train delays is extending across some operators.

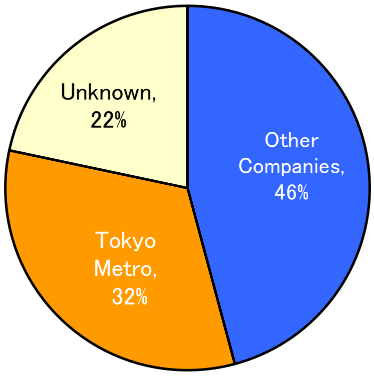


Figure 3 – line of the delay occurrence

3. CAUSES OF THE TRAIN DELAY

Data on dynamic operation is absolutely necessary to grasp actual state of the mechanism of worsening punctuality. So we got the actual data from Centralized Traffic Control (CTC) where data is recorded on the departure and arrival time of every train at each station. Figure-4 shows an increased travel time of each train against the train schedule for a specific link consisting of 15 stations. It usually takes about 20 minutes to travel along the entire line. It seems during the early rush hours, the station dwell time is a major cause of the train delays. However, the train running time becomes the major cause during the later rush hours. So it would appear that the train delay is occurred by increases in the dwell time and then its influence extends to the train running time. In other words, the train delay is caused by the passenger factor and later on extends to the train operation factor. Therefore, management of passenger flow offers a basic measure for controlling the increase in the train dwell time and thus becoming one of the effective measures to the problem of train delays.

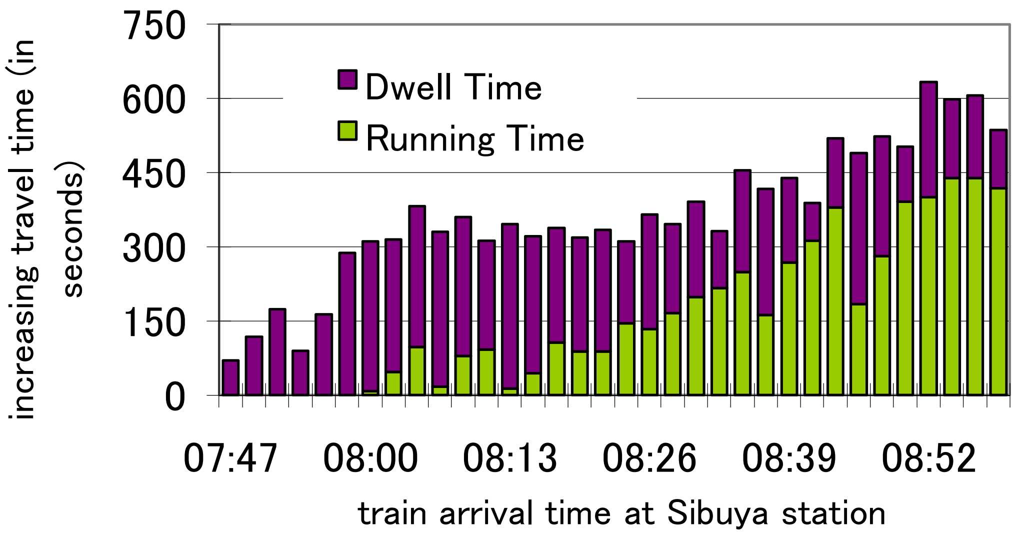


Figure 4 – increased amount of travel time

4. THE FRAMEWORK OF SIMULATION SYSTEM

The mechanism of chronic train delay occurrence in the TMA railway network is described as follows. Firstly, passengers on a platform congregate in the front of train doors where are located near escalators and/or stairways. Those passengers surge to the doors when the train arrives at the station. During rush hours, the boarding and alighting processes are not smooth because of crowded in the train. Therefore, the train stopping time becomes longer. Secondly, the following train may have to run with gradually decreasing speeds owing to the departure delay of the forward train. The decreasing of the speeds is propagated to other following trains in consequences. Finally, the awfully crowded on the platform occurs due to the accumulated delays of train arrivals at the station. This makes the stopping time of a train at the station become extremely longer. The causes of the train delays in the TMA railway network are explicitly represented by such a vicious circle.

A simulation system which can reproduce the above-mentioned phenomenon is necessary to examine measures for reducing train delays. The simulation system is composed of three sub-systems. The first sub-system is for analysing passengers flow in a railway station. This sub-system outputs the passenger volume per transfer route and it is the focus of this study. The second sub-system is to analyse passengers' train boarding/alighting behaviour. This sub-system outputs the train stopping time. The third sub-system is for analysis of velocity control behaviour of train operators. This sub-system outputs the time required to go between stations. Figure-5 shows the framework of simulation system for the analyses of train delay.

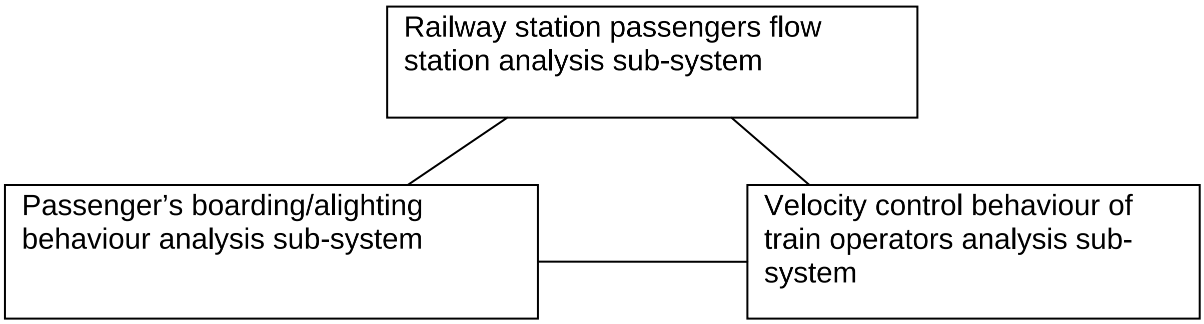


Figure 5 - The framework of simulation system for train delay analysis

5. THE PASSENGER FLOW IN STATION ANALYSIS SYSTEM

5.1 System composition

Major subjects of the system are passengers' walking route choice behaviour and walking behaviour in a railway station. The walking route means the transfer route from the train to the exit/entrance of the railway station, Thus, the passengers' walking route is influenced by the train's door choice behaviour, the escalator/stairway choice behaviour, the ticket gate choice behaviour, and the exit choice behaviour. On the other hand, the passengers' walking behaviour means overtaking behaviour, avoidance behaviour and so on. This study applies the result of another existing study on these behaviours to the simulation system.

5.2 Passenger walking route choice behaviour model

The study applies the railway passengers' walking route choice behaviour model which is developed by the Institution for Transport Policy Studies in Japan. The model is a disaggregate multiple logit model and it is estimated with the data that was collected by a survey that tracked the movement of passengers between ticket gates at a big terminal in Tokyo's railway network. The simulation system outputs the passenger volume each walking route. The model and its parameters are shown as follows:

$$P_i = \frac{\exp(V_i)}{\sum_j \exp(V_j)}$$

$$V_i = \alpha_1 X_1 + \alpha_2 X_2 + \cdots + \alpha_n X_n$$

P_i: probability of choosing route i
V_i: utility of route i
α_i: parameters to be estimated
X_n: explanatory variables of the utility function

Table1 Parameters of the Passengers' Walking Route Choice Behaviour Model

	Parameters	t-value
The time of horizontal transfer (min)	-1.806	-12.9
The time of vertical transfer (min)	-2.204	-2.18
The number of the passengers flow confluence points	-0.281	-7.27
Likelihood Ratio	0.428	
Hit Ratio	74.5%	
The number of samples	650	

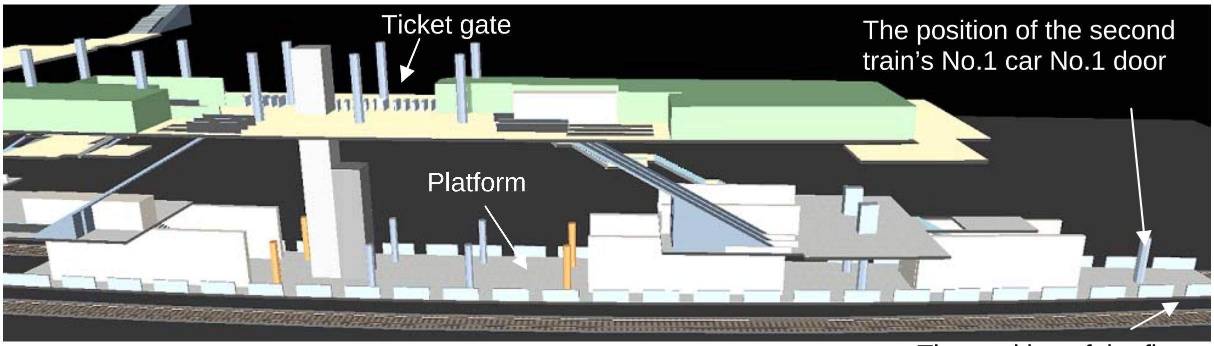
5.3 Passenger walking behaviour model

The study applies the VISSIM for simulation of passengers' walking behaviour. In the VISSIM, the walking behaviour of pedestrians is based on the Social Force Model. The model expresses the pedestrian walking behaviour by the forces analogously to Newtonian mechanics. The VISSIM needs an input of the setting of the walking route from start point to the destination point each pedestrian. The result of the passengers' walking route choice model inputs to the setting.

6. CASE STUDY

6.1 Subject station of analysis

The subject station of analysis is the terminal station in the central area of Tokyo. The number of passengers per day of this station is approximately ninety thousands. The trains arrive every three minutes and almost are the getting off passengers during the morning rush hours. The train has six cars each has 4 doors. Figure-6 and 7 shows the overall structure and the ticket gate layout of this station.



The position of the first train's No.1 car No.1 door

Figure 6 - Drawing of overall structure of the subject station

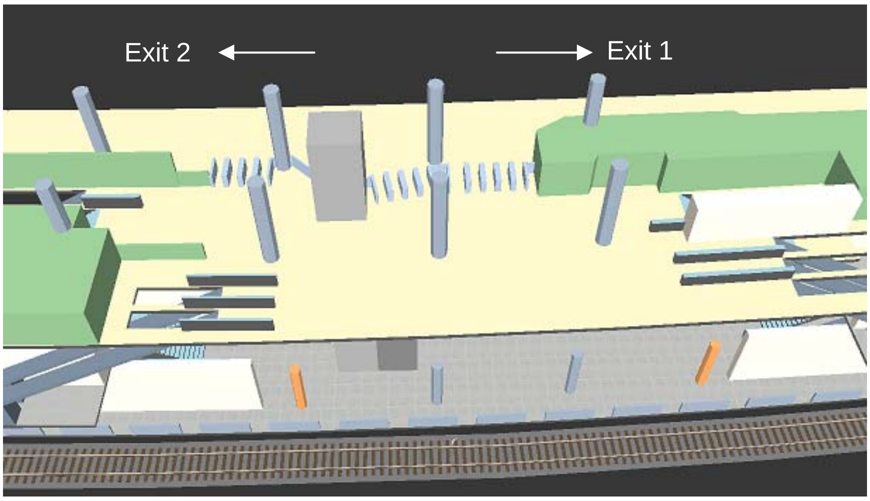


Figure 7 - Drawing of the ticket gate layout

6. 2 Survey for collecting verification data

This study verifies the representability of the railway station passenger flows of the simulation system by comparing the actual data with the estimated results in term of passenger volume each train door. The actual data are acquired from video cameras which were set on the ceiling of the platform. Table-2 shows the number of passengers getting off each door of two trains during morning rush hours. Also the number of each direction of passengers who got out of the ticket gate was counted at the station.

Table 2 -The number of passengers getting off each train door

Car No.	Door No.	The first Train	The second Train
1	1	6	5
	2	6	5
	3	17	22
	4	29	33
2	1	48	60
	2	63	75
	3	45	62
	4	35	41
3	1	40	46
	2	50	59
	3	73	88
	4	46	56
4	1	28	34
	2	18	23
	3	20	17
	4	16	7
5	1	20	23
	2	18	24
	3	18	23
	4	17	21
6	1	18	21
	2	32	40
	3	61	72
	4	33	34
Total		757	891

6. 3 OD data for simulation

The OD data of passengers for simulation is made from the number of each direction of passengers who got out of the ticket gate. Table 3 shows the OD table for simulation.

Table3 The OD table for simulation

	Exit 1	Exit 2	Total
The first Train	38	719	757
The Second Train	47	844	891
Total	85	1,563	1,648

6. 4 Renew of LOS of network data

The network data of the passengers' walking route choice behaviour model is made from the drawings of the station. The nodes are set on the centroid in the train, the position of train's door, escalator, stairway, ticket gate and exit of station. Links which are composed of these nodes have link times calculated from the distance and passengers' average walking speed. However, if the congestion in the link occurs, the time is to be longer than the calculated time. Therefore, the simulation feedbacks the time each link which outputs from the VISSIM to the network data for the passengers' walking route choice behaviour model. The iteration of simulation is continued until the passenger volume each door converges.

6. 5 Result of simulation

The passenger volume of each door converged by five iterations. Figure 8 shows the RMS error about passenger volume of each door each iteration. The RMS error converged around sixteen passengers. On the other hand, Figure 9 shows the scatter diagram of the fifth iteration. The coefficient of correlation about actual data and estimated data is 0.676. From these results, the reappearance of the passenger flow in station analysis system is not enough. The passengers' walking route choice behaviour model and walking behaviour model is needed improvement of these model parameters.

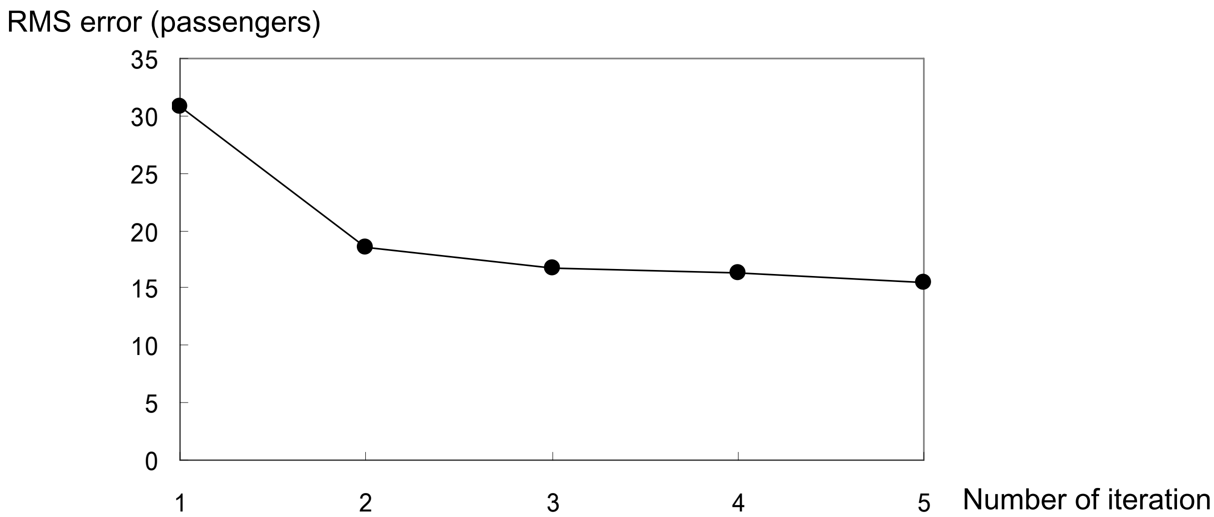


Figure 8 -The RMS error of each iteration

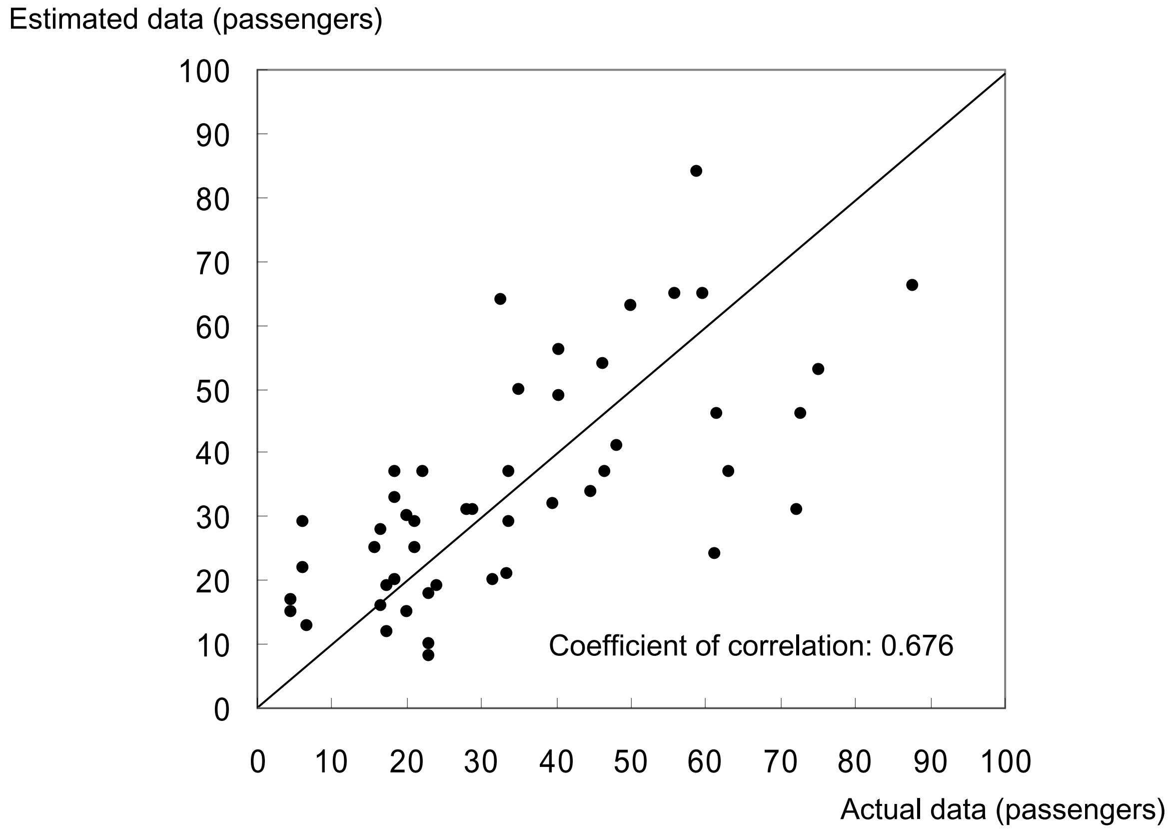


Figure 8 The scatter diagram of the fifth iteration

7. CONCLUSION

The study considered the cause of the chronic train delays in the TMA railway network and showed the framework of the simulation system for examining measures to decreasing train delay. Moreover, the passenger flow in railway station analysis system, which is one of the sub-systems of the simulation system for analysis of train delay, was developed. The verification of the appearance of the analysis system was not enough. We conjecture that the parameters of the passengers' walking route choice behaviour model and walking behaviour model are not appropriate. In particular, the passengers' walking route choice model was estimated with data that were acquired by pursuing transfer passengers between ticket gates. Therefore, it is impossible to capture enough key factors of passengers' car choice behaviour and door choice behaviour. It is necessary that we need to carry out additional surveys to acquire these choice behaviour data. Also, the subject station of analysis is characterized by the majority of getting off passengers. Further verification is necessary to conclude whether this analysis system can be applicable to the station which has large numbers of getting on and off passengers. To do so, development of other sub-systems may remain a future work.

ACKNOWLEGEMENT

The study described in this paper was supported by JSPS (Japan Society for the Promotion of Science) under the Grants-in-Aid for Scientific Research (B) 21360242.

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