A STUDY ON COORDINATION BETWEEN URBAN DEVELOPMENT AND STATION CAPACITY

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ABSTRACT

In Tokyo, recently, rapid urban developments around railway stations in the city centre have been causing serious overcrowding at stations, in particular, the crowding of passengers on station platforms. We consider that causes of the overcrowding at the city centre stations are: (1) the lack of clarity in the relationship between the floor area of buildings and the station capacity, (2) the railway is not included in the traffic impact assessment, (3) the ability for station facilities to handle an increase in passengers is not clearly understood, (4) there is no framework to discuss the countermeasures for the overcrowding of stations.
Therefore, this study tries to study toward solutions for preventing the overcrowding at stations caused by urban development in the city centre. Concretely, this study focuses on three points. (1) It identifies and lists up causes of the overcrowding at city central stations in Tokyo. (2) Next, conducts a fact-finding survey of the overcrowding at stations. In this study, we measure the number of outgoing passengers per second at the peak hours, which is changing moment by moment, in order to find how much the station facility can accept the increase of passengers. (3) Lastly, based on the results of (1) and (2), we suggested what should be improved institutionally to prevent serious overcrowding exceeding the capability after deciding how the station can adequately handle the increase of passengers.

Keywords: Overcrowding of passengers at a station, Urban development, Deregulation of the city planning, Traffic impact assessment, Maximum outgoing passengers

1. INTRODUCTION

There are four types of congestion problems in the railways in Japan: the overcrowding of passengers on a train, the overcapacity of a railway track, the overcrowding of passengers at a station and the traffic jam caused by a busy railway crossing. Many countermeasures have been implemented to solve these problems, mainly the problem of the overcrowding on a train.

In fact, the overcrowding on trains has been slowly relieved by improving transport capacity with construction of new lines, multiple tracks, more frequent operations and longer trains. On the other hand, although the overcrowding at a station has existed for a long time, few research has been conducted on this matter, and most discussions were focused on the overcrowding of passengers getting on and off a train at a terminal station (Yamashita, et al, 2007 and Hibino, et al, 2004). However, recently, urban developments have been rapidly implemented around city central stations in Tokyo, resulting in serious overcrowding at stations.

The urban development in the city centre contributes to urban activation, and provides great benefits. On the other hand, in large cities in Japan such as Tokyo, the urban development is concentrating around railway stations in high economic areas. This introduces the increase in high-localized traffic demand, which causes more overcrowding of the station. This results in an overflow of passengers on the platform due to inadequate station capacity. In addition to the overcrowding at stations, the increase of the time required to board and disembark causes longer stopping time, even leading to delays for subsequent trains (Hibino, et al, 2012 and Kariyazaki, et al, 2011). Similar problems might become severe in mega-cities where population is increasing rapidly, especially in Asia.

The main reasons for the above problem of the overcrowding at railway stations are as follows. (1) While people migrating back to the city centre became more evident in the Tokyo Metropolitan Area from the late 1990s, a new law to deregulate the city planning (i.e. land use and flow area ratio of buildings) was established in 2002. (2) In Japan, the traffic impact assessment is introduced as a countermeasure for traffic related to urban development. However, although the modal share of railway transport in the city centre of Tokyo is extremely higher compared to most countries in the world, the railway is not included in the assessment.

In fact, although only 10 years has passed since Kachidoki Station in Tokyo opened, urban development projects were rapidly implemented around the station following the deregulation of the city planning, and this resulted in an insufficient capacity at the station. And now, a redevelopment project along Ring Road No.2 (the road between Toranomon and Shimbashi) is being implemented, severe overcrowding is expected at neighboring stations in the future. Therefore, serious overcrowdings are actually occurring at some stations in Tokyo, and urgent solutions are required.

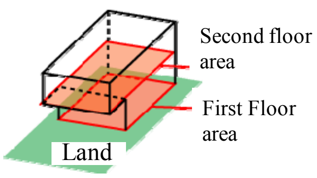
As shown above: (1) rapid urban development around a station brings immediate loads on the station, and the overcrowding from this causes delays of trains, (2) urban development usually concentrates in important areas and the areas with heavy traffic (in such areas, a high-density railway network has already been introduced, adding a new line in the future is difficult), (3) the improvement of the station takes a long time and is quite expensive. In addition, due to physical restrictions, the improvement of the station is sometimes difficult. Therefore, it is important to grasp whether the station can adequately handle the increase of passenger traffic volumes (increase of the floor space) prior to the planning, and it is necessary to consider countermeasures for the overcrowding related to the urban development in the planning stage. However, there is almost no research to solve this problem.

In order to prevent serious overcrowding at stations by urban development in the city centre, this study aims (1) to reveal the reality of overcrowding at stations and (2) to suggest possible solutions and countermeasures for such overcrowding.

2. CAUSES FOR SERIOUS OVERCROWDING AT CITY CENTRAL STATIONS IN TOKYO

2.1 Reasons for the Increase in the Floor Area of Buildings in the City Centre of Tokyo

First, we will explain the regulation of the floor area ratio of buildings (hereinafter FAR) [Note 1] which is the base of the urban development in Japan. The regulation of the FAR was established in the 1960s, the main purpose of which is to balance the floor area of buildings and the capacity of public facilities such as roads and sewages. Concretely, the maximum FAR is regulated per land usage [Note 2] (Figure 1). However, (1) the regulation is loose and post-fact ratification with the consideration of existing high FAR buildings and therefore, the maximum FAR is set higher than an appropriate value in comparison with the actual improvement of infrastructure. (2) FAR does not apply to the railways.
Also, due to the unclearness of relationship between the capacity of public facilities and the floor area of buildings which is to be the basis of the regulation of the FAR, when the argument of efficient land use became active, the deregulation was requested by urban developers, such as the Comprehensive Design System (the premium of the FAR are permitted) was established for deregulation. For example, Comprehensive Design System allows a higher FAR as public contribution if the buildings includes open space for the public [Note 3] (Figure 2).
Moreover, in 1998, the Japan Economic Strategy Council was established as an advisory body of Prime Minister Obuchi, and Economic Planning Agency Head Sakaiya proposed the deregulation of the city planning. Following which, the 'Strategy of the production of the Economy in Japan' was submitted a report in 1999. As an administrative response for urban revitalization based on the report, legal enactments and re-enactments such as the Act on Special Measures Concerning Urban Revitalization were implemented in 2002, and the regulation of the city planning (including land use and floor area ratio of buildings) was significantly eased.
In Tokyo, these movements resulted in an acceleration of the redevelopment of the city centre, which has emerged since the late 1990s, and the floor area of buildings has been rapidly increasing mainly around stations in the high-economic areas (Figure 3).
Concretely, looking at the locations of super high rise buildings built in the last 10 years, they were concentrated around specific stations such as Tokyo, Otemachi, Shimbashi, Shiodome,



Floor area ratio (%)
$= \Sigma Ai/B \times 100$
Ai : Floor area of i-th floor
B : Land area
Ex. Maximum floor area ratio
for a commercial premise: 1,300%

Figure 1 – Regulation of Floor Area Ratio for Buildings

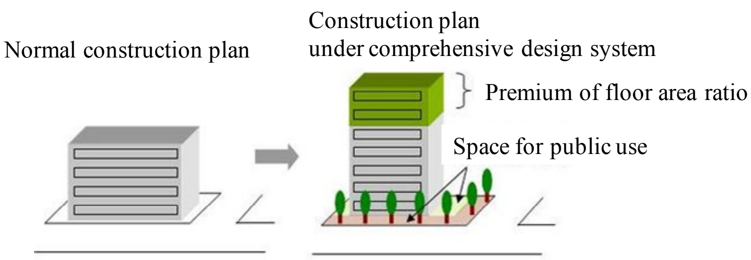


Figure 2 – Outline of Comprehensive Design System

Shinagawa, Roppongi, Kamiyacho, Kachidoki, Osaki, and more redevelopments are being planned around these stations in the future (Urban Renaissance Agency, 2011).
As a result, the number of passengers has rapidly increased in a short time at some stations since the year 2000. However, as the general trend, looking at the transition of the number of passengers by the Tokyo Metro, it is decreasing after the peak in 2008 (Figure 4). From these points, although the decrease of railway passengers is expected due to the decrease of population, overcrowdings at specific stations shown above possibly become serious.

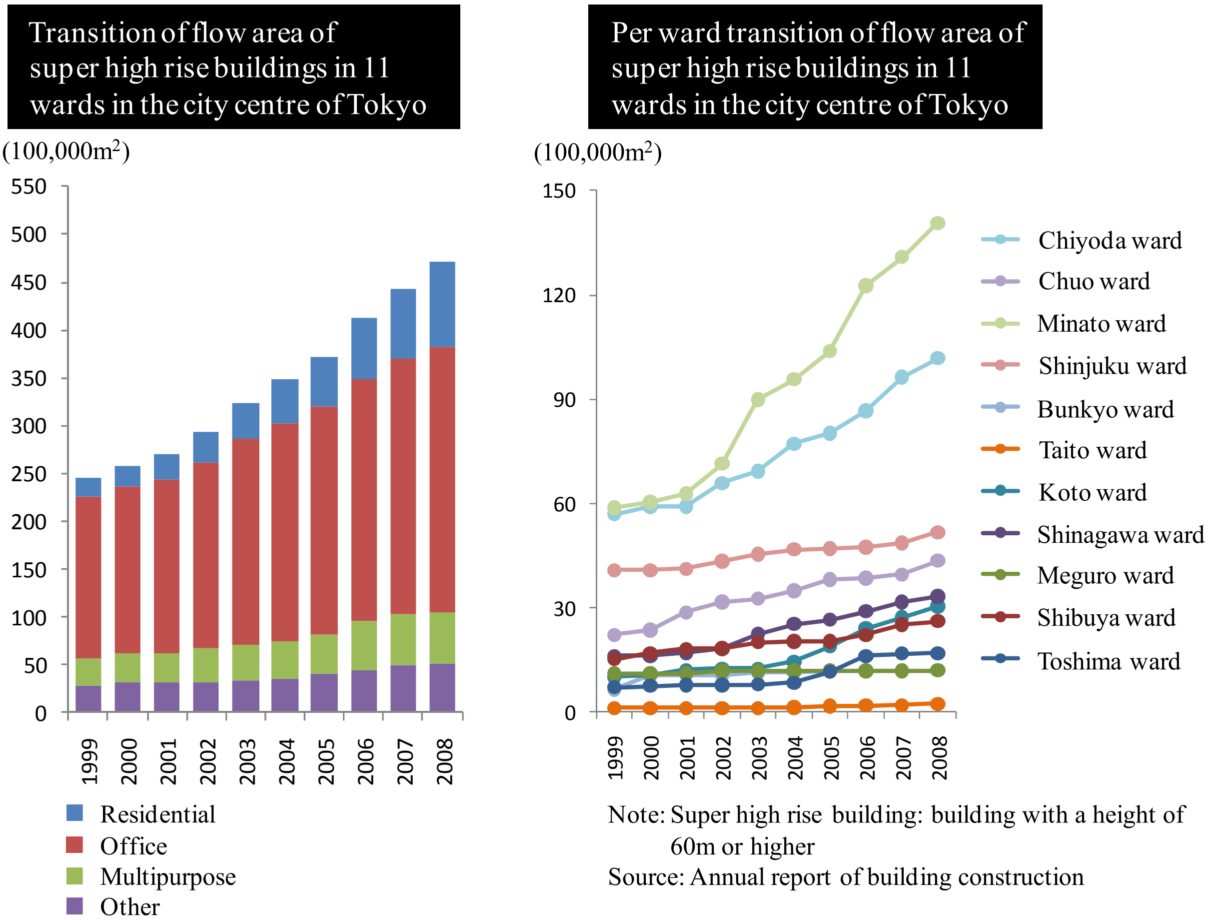


Figure 3 – Transition of Flow Area of Superhigh-Rise Buildings in 11 Wards in the City Centre of Tokyo

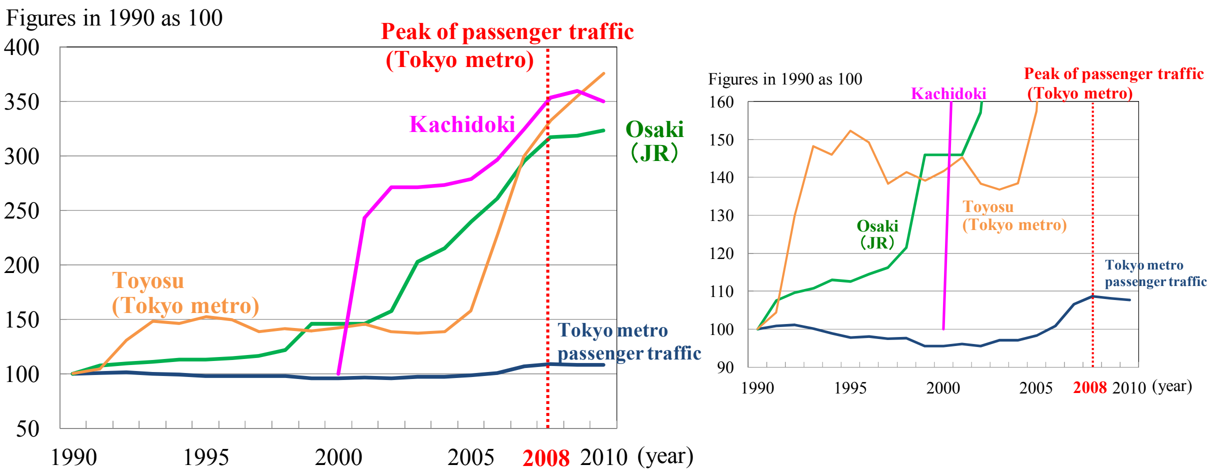


Figure 4 – Transitions of the Number of Passengers Caused by Urban Developments

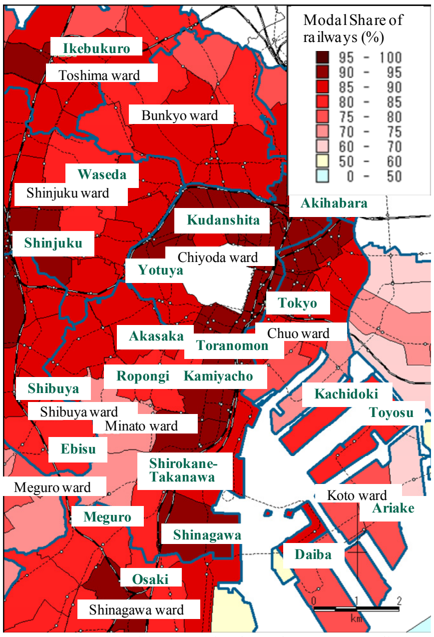
2.2 Reasons Why the Station Improvement Comes after the Overcrowding Becomes an Issue

2.2.1 Problem of the Traffic Impact Assessment in Japan

In Japan, in the case of higher loads on transportation facilities, a traffic impact assessment (hereinafter TIA) is introduced as a countermeasure for traffic relating to urban development. However, (1) although the modal share of railways is extremely higher in the city centre of Tokyo compared to most cities in the world, the railways are not included in the assessment (Figure 5). (2) It is not clearly grasped how much the station facility can accept the increase of passengers. Especially about (1), in Europe and the United States, the modal share of railways is low, and the capacity of the public transportation is enough. Therefore, the constraint of the capacity of road facilities is larger and transport facilities are improved correspondent to the urban development from the view of the promotion of the public transportation usage and the reduction of the private car usage. But, in Japan, although the TIA was introduced referring to examples in Europe and the United States, as shown above, the modal share of railways is extremely high. Furthermore, railway operators have a legal obligation to accept the demand. Thus, it means that appropriate TIA considering the true situation in Japan has not been implemented. The problem about (2) is explained at 3.1.2.

2.2.2 The Station Improvement Comes after the Overcrowding Becomes an Issue

Also, when the station facility is improved as the countermeasure for easing the overcrowding caused by the urban development, it comes after the overcrowding becomes an issue. Now, for example, during the morning peak time at Toyosu Station in Tokyo, passengers are jamming from the ticket gate floor to the platform. It was determined that a large-scale improvement was needed in order to ease overcrowding (Figure 6), but the reason is adding to the problem that the TIA does not include the railway as shown above, there is no framework for the urban developer and the railway operator to discuss the solution to the overcrowding.
In Japan, in some case of large-scale urban developments, the developers and the railway operators collaborate to manage the expansion of railway stations. However, individual building developments plans are not discussed with railway operators. Therefore, the railway operator is not able to access the details of the urban development, and the station is exposed to serious overcrowding caused by the urban development without any consideration of a countermeasure. The station is then improved to ease the overcrowding after it becomes inevitable. Then, it takes much time for grasping the situation, the planning and the reconstruction of the station improvement. While the planning and the reconstruction of the station improvement is underway, due to continuing other urban developments, passengers continue to increase and this causes even more serious overcrowding, thus causing more frustration to train users (Figure 7).
In consideration of all the points listed above, the reasons for serious overcrowding at railway stations in the city centre of Tokyo are shown in Figure 8. Although it is not explained in detail in this paper, one of the reasons of the above overcrowding is that the subsidy for the station improvement in order to ease the overcrowding is restricted for underground stations in Japan.



Source: Person trip survey in the Tokyo Metropolitan Area

Figure 5 – Modal Share of Railways in the All-Purpose in the City Centre of Tokyo

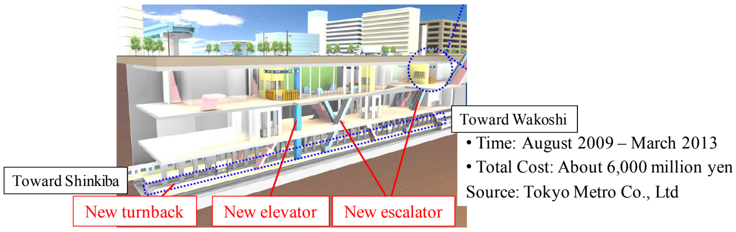
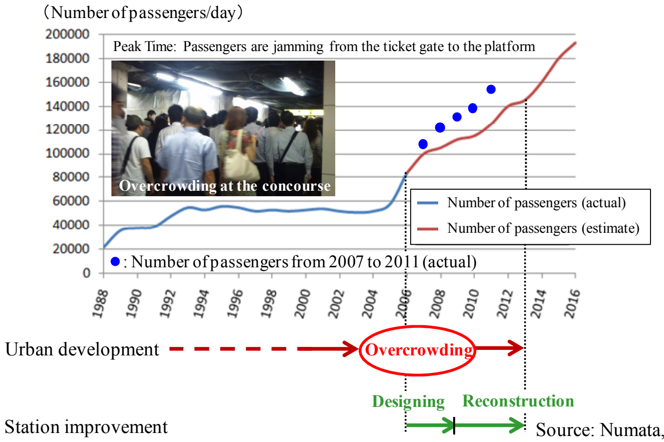


Figure 6 – Large-scale Improvement of Toyosu Station



Source: Numata, et al, 2009

Figure 7 – Prediction of Future Number of Passengers at Toyosu Station

Floor area of buildings rapidly increases in the city centre

- Regulation of the floor area ratio of buildings※1
  - (1) A Loose regulation
  - (2) Does not include railways
- Various deregulations institutions

↓ Since 2000

- Redevelopment of the city centre
  ＋Regulation of the city planning was significantly eased

↓

Rapid urban development around railway stations in the city centre

Counter-measures for Traffic ⇒

Station improvement comes after the overcrowding becomes an issue

- Traffic impact assessment※2
  - Dose not include railways
  - How much the station facility can accept the increase of passengers →Unclear
- No framework for city side and railway side to discuss the counter-measure for the overcrowding
- Subsidy for the improvement of the station
  →Only Applied for underground Stations

※1 Regulation of the Floor Area Ratio of buildings: A regulation to balance the floor area of buildings and the capacity of public facilities such as roads and sewages

※2 Traffic impact assessment: In the case of higher load on the transportation facility
→Improvement of the transportation facility to correspond with the urban development

↓

Serious overcrowding occurs in city centre stations

Figure 8 – Causes for the Overcrowding at the City Centre Stations in Tokyo

3. STUDY OF THE MAXIMUM OUTGOING PASSENGERS FOR A STATION FACILITY

In this chapter, from the issues clarified in the previous chapter, we explain the results of analyses for clarifying ‘how much the station facility can accept the increase of passengers’.

3.1 Method of Fact-Finding Survey

3.1.1 Focus Point of the Fact-Finding Survey

In this study, a station in the city centre of Tokyo which has serious overcrowding caused by urban development is targeted, and we measured the number of outgoing passengers per second at the peak time which is changing moment by moment. A fact-finding survey was conducted (1) to grasp the reality of the overcrowding (what is actually happening at the station), (2) to see what is happening when all passengers from the preceding train have not left the platform before the doors of the next train open, and (3) to clarify how much the station facility can accept the increase of passengers.

As shown in Figure 9, bottlenecks occur in various places at a railway station, such as a jamming of passengers in front of the stairs/escalator of the concourse, which leads to the jamming at the platform. Also, a jamming in front of the stairs/escalator outside the ticket gates leads to the jamming inside the ticket gates, thus a chained overcrowding reaction occurs. In this study, from the above bottleneck places, we focused on the flow of disembarking passengers at the stairs/escalator at the platform, where the overcrowding is the most severe and which is also an important place for the safety of passengers among above places, and conducted a fact-finding survey. The survey was conducted at a railway station with two platforms and four tracks (as shown in Figure 10), and passenger traffic volumes were counted when passengers passed the bottom edge of the stairs/escalator.

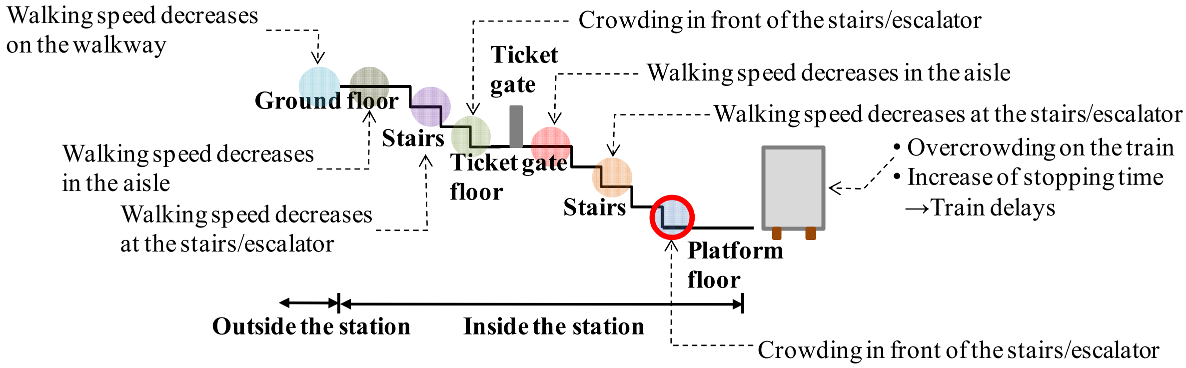


Figure 9 – Bottleneck Places Where Overcrowding Occurs in a Railway Station

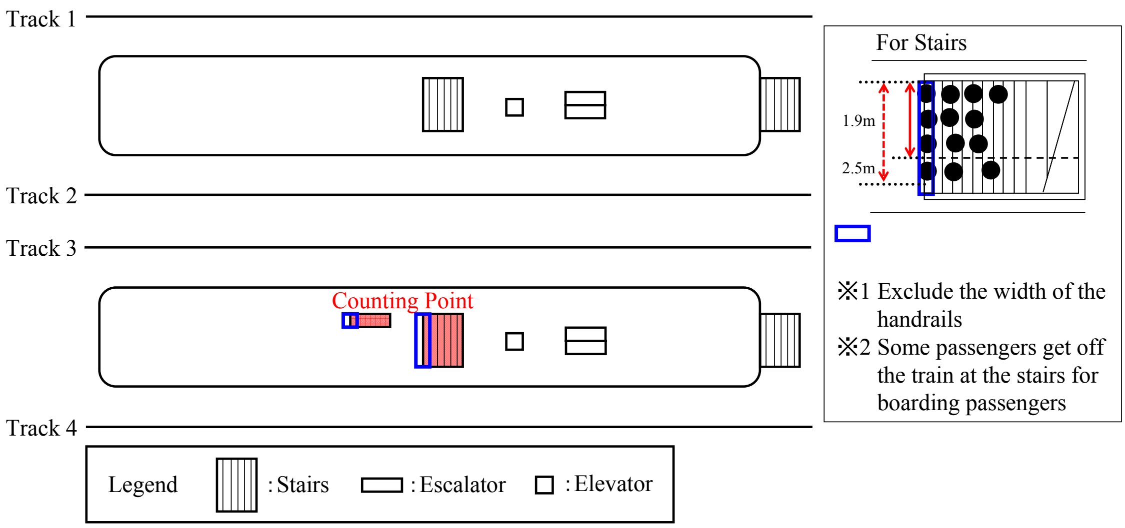


Figure 10 – Overview of the Fact-Finding Survey at a Railway Station

3.1.2 Current Design Capacity of Station Facilities in Japan

Though Suzuki, et al. (2012) studies the current design capacity of station facilities in Japan, there is no common standard, and each railway operator sets their own standard. Therefore, those design capacities are largely different from each other. The design capacity of station facilities is targeted based on average traffic volumes per train during the peak 30 minutes, calculated from the view of 'average traffic volumes at the peak time' which whether passengers can easily outgo before the doors of the next train open (Railway Bureau, Ministry of Land, Infrastructure, Transport and Tourism in Japan, 2007).

On the other hand, as shown in Figure 11, passenger traffic volumes change greatly depending on the time of day and therefore the remnant of passengers may occurs at a certain time. The impact of the remnant of passengers and how many passengers should be allowed in the station facility is not yet clear. For these reasons, not only average traffic volumes at peak time, but also the analysis of outgoing passengers at the station facility by each train is needed.

3.1.3 Method of Fact-Finding Survey

In Japan, passenger traffic volumes at the station facility are grasped only on a per-minute basis, as shown in Figure 12. However, to analyse the outgoing passengers by each train which change moment by moment at the station facility from the time when train doors are opened to the time when doors of the next train are opened, per-second passenger traffic volumes needs to be counted. Using a manual counter and a video camera is the general method for counting passengers at the station facility. However, it is difficult to count passengers per second with the manual counter. The video camera also has the following drawbacks: (1) From a privacy protection perspective, it is impossible to obtain data at the random spot. (2) The cost of setting up video cameras for a large-scale survey may be expensive, (3) Setting up the video camera on the ground using the tripod stand may disturb the passenger's flow. Also, studies were conducted using a laser scanner to count passengers (Zhao, et al, 2001). Though it is available during off-peak hours when there are small traffic volumes, but occlusions and errors of multiple passengers being counted as one person may occur at the peak time.

Therefore, as a method to count passengers per second at a random spot and obtain the data as cost effectively as possible, we developed a passengers counting system using a mobile phone. This system applies Java to count passengers per second by interlocking the clock function and counter function on the mobile phone and enables per-second counting. We also believe that the system is ubiquitous due to the use of the mobile phone. As the verification of the system, we counted the number of passengers passing the two escalators at the platform of a station in the city centre (a different location from the one shown in Figure 10) using both the phone system and a video camera for 10 minute intervals [Note 4]. As a result, the average error was about 0.3% (an average of 18 samples) (Figure 13). The error is mainly due to human error, and the system has the required accuracy. The result of the survey is shown at 3.2. It is considered that this method is useful as a survey method because we were able to successfully clarify the focus points of the survey in 3.1.1, which had been difficult to clarify before.

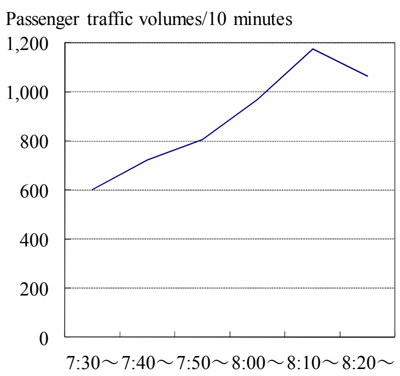


Figure 11 – Passenger Traffic Volumes by Time at Stairs (Measured Place, every10 Minutes)

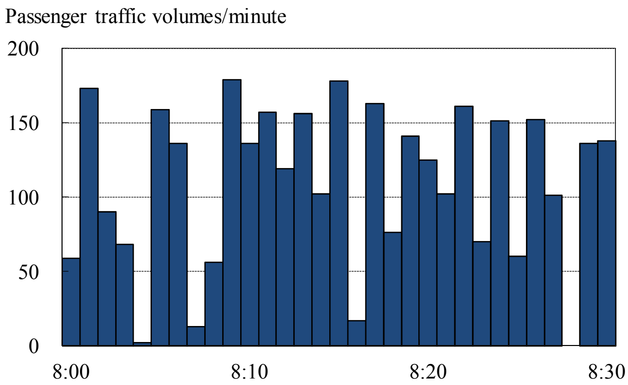


Figure 12 – Passenger Traffic Volumes by Time at Stairs (Measured Place, per Minute)

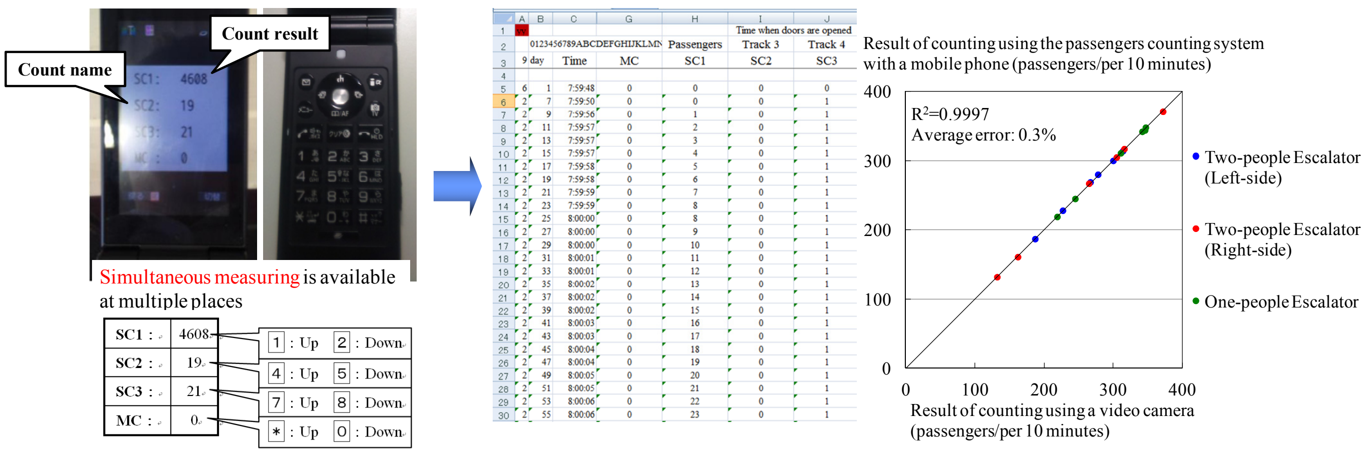


Figure 13 – Passengers Counting System Using a Mobile Phone

3.2 Analysis of Overcrowding at the Station

3.2.1 Flow of Disembarking Passengers from a Train at the Stairs/Escalator at the Platform

(1) Passenger's Flow at the Stairs

We analysed how disembarking passengers from a train are handled at the stairs, and what kind of phenomena occur if the passengers are remaining when the doors of the next train are opened.

We counted passengers per second at the most crowded time and plotted the result on a graph with passenger traffic volumes every 10 seconds on the ordinate and time on the abscissa (Figure 14). The following phenomena became clear.

(a) During the time when overcrowding becomes severe, passengers shorten the space between themselves when getting off the train, and passenger traffic volumes reaches its peak. However, by the existence of slow walkers and people who squeeze in from the side, gradually the walking speed decreases (i in Figure 14). Eventually, the congestion situation by walkers occurs, and outgoing passengers becomes constant (ii in Figure 14).

(b) Then, though passengers decrease and the congestion situation disappears, when the jamming in front of the stairs is not cleared before the doors of next train are opened, depending on remaining passengers of the previous train, walking speed decreases and processing capacity drops largely compared with the case when the jamming is cleared (iii in Figure 14).

Next, we analysed how the way of passengers outgoing changes depending on traffic volumes (the number of disembarking passengers per train). When we counted passengers who disembarked at the stairs for disembarking passengers (excluding passengers who disembarked at the stairs for boarding passengers) on a different day, we found that regardless of the volumes, flow rate (passenger traffic volumes per unit time) at the congestion situation time does not change and the length of the congestion situation time changes (Figure 15).

Considering the above results, when trains of the same headways and same traffic volumes continue, the following phenomena occur if passengers are remaining before the doors of the next train are opened (Figure 16).

(a) Due to the remnant of passengers and the decrease of the processing capacity (slower walking speed) at the stairs, the time required for those passengers to pass the stairs increases. Because this phenomenon also occurs at other places, such as the ticket gate and the stairs at the exit, the total amount of time to the exit is increased by the

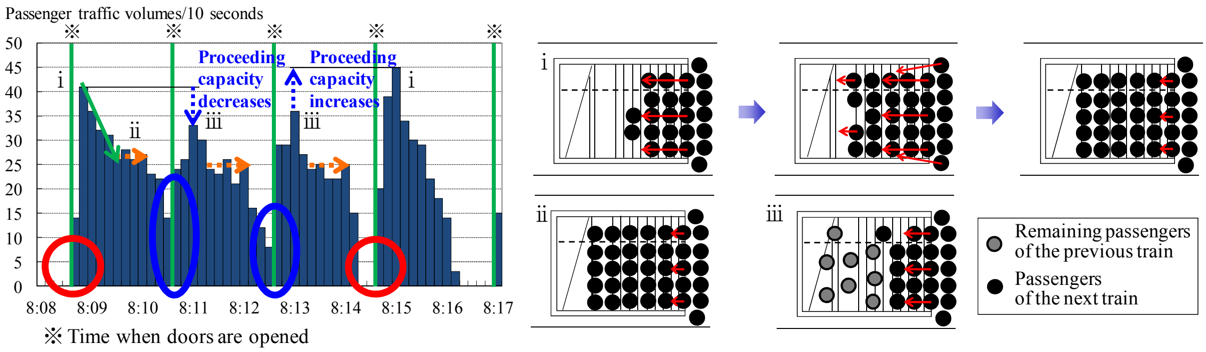


Figure 14 – Traffic Volumes of Disembarking Passengers from a Train at the Stairs

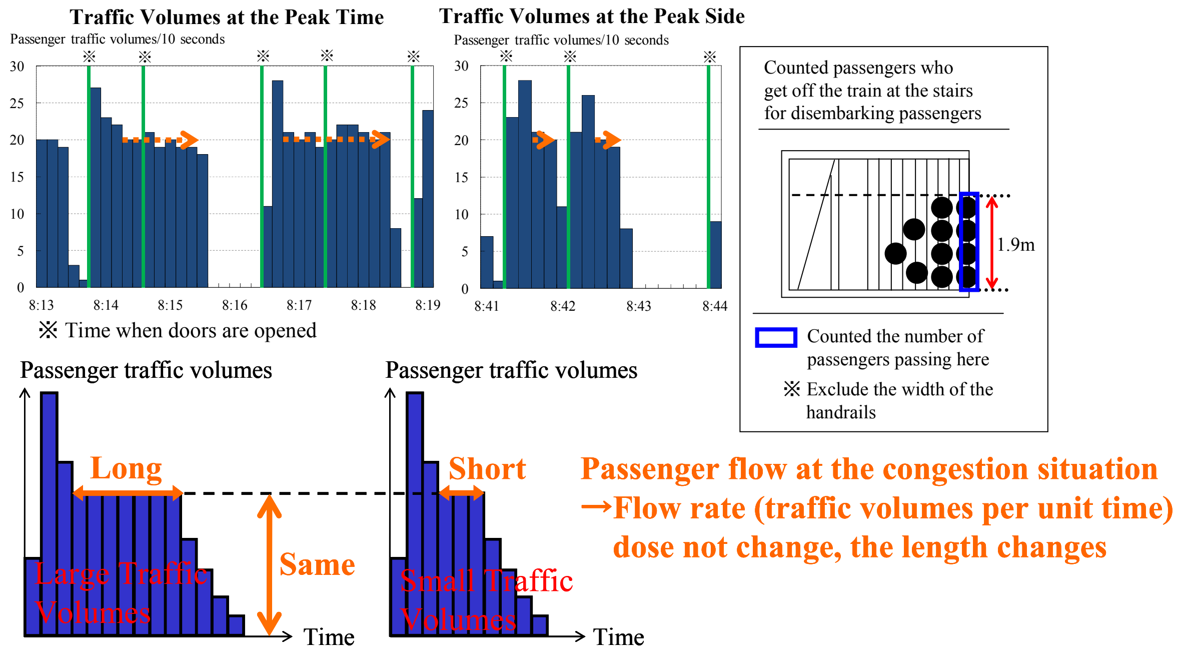


Figure 15 – Difference of Outgoing Passengers by Traffic Volumes

combination of these.

(b) As well, the remnant of passengers expands by the decrease of the processing capacity of the stairs.

In reality, as mentioned in 3.1, passenger traffic volumes at peak time when presented on a graph is mountain-like in shape with the summit at 8:10-8:20, and the passenger traffic volumes change significantly depending on the time of day. Therefore, if the remnant of passengers occurs at the time of low traffic volumes rather than at the most crowed time, more passengers remain compared to Figure 16. By this, the jamming of passengers on the platform rolls into a snowball, and results in remaining passengers from previous trains are overflowing when doors of next trains are opened (Figure 17).

According to our measurements, all passengers from one train must be cleared before arrival of the next train as shown in the left picture of Figure 18 (from the result on a different day). However, as shown in the right picture of Figure18, those passengers are not cleared, they are chained to the passengers from next train, and the phenomenon of disembarking passengers from previous trains are overflowing at the platform when doors of next trains open really

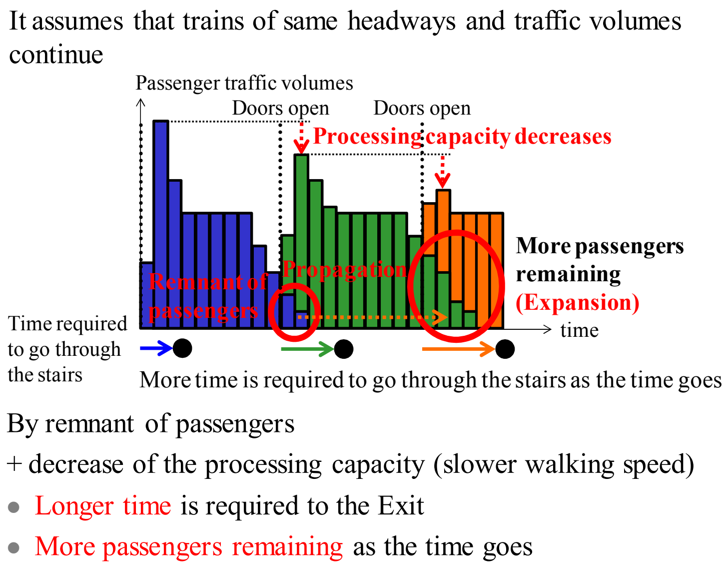


Figure 16 – Expansion of the Remnant of Passengers at the Stairs (1)

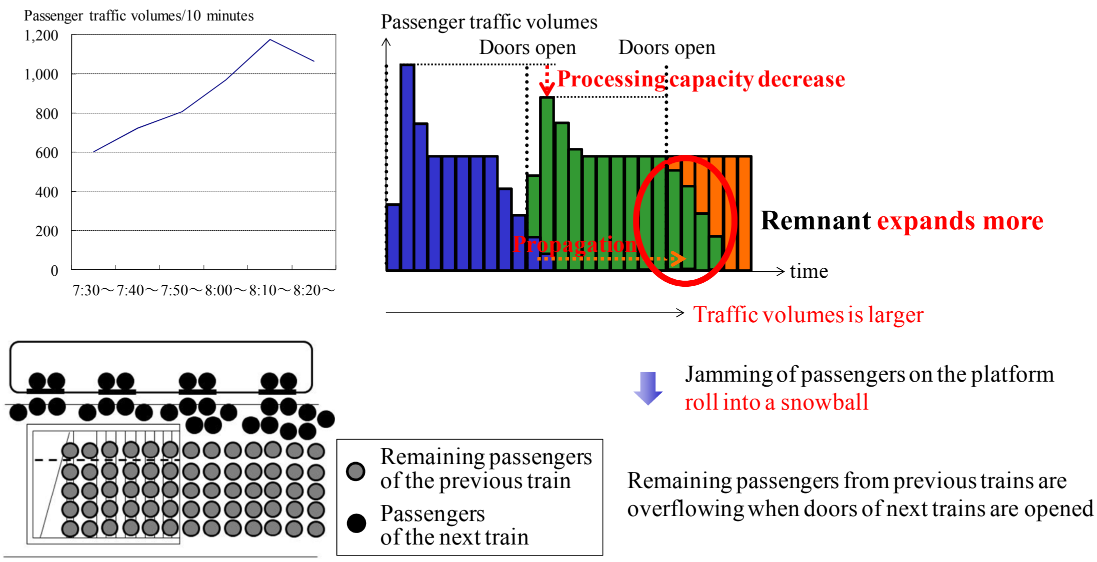


Figure 17 – Expansion of the Remnant of Passengers at the Stairs (2)

occurs. The above situation increases the risk of an accident when getting off the train or falling down from the platform, and the increase of the time required to board and disembark causes longer stopping time, even leading to delays of subsequent trains.

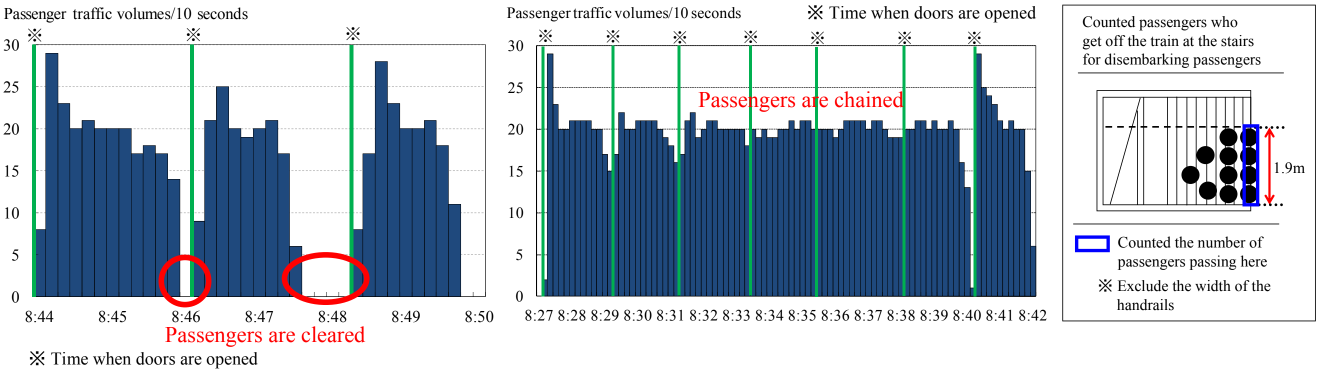


Figure 18 – Example of the Remaining Passengers from the Previous Train Affect Subsequent Train Badly

(2) Passenger's Flow at the Escalator

Similarly, we analysed moment to moment changes of how disembarking passengers from a train are handled at the escalator. In Tokyo, in general, passengers who use the escalator stand on the left side, and the right side is used by walkers. However, we found that the passenger's flow changes irregularly (Figure 19). The following can be considered as reasons for this.

(a) This is due to the fact that some passengers walk up on the left side in the case that there are no remaining passengers from the previous train when the doors open (left ⅱ).

(b) In contrary, the processing capacity decreases because some passengers were slow or stand even on the right side (right ⅱ).

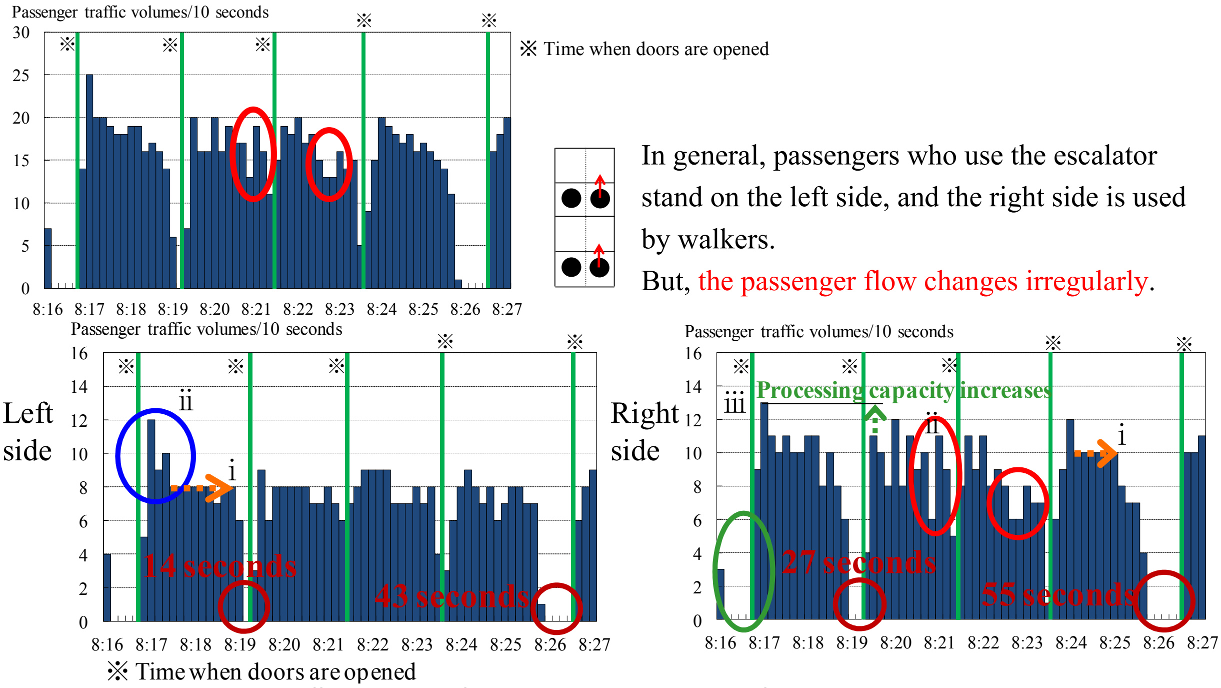


Figure 19 – Traffic Volumes of Disembarking Passengers from a Train at the Escalator

(c) If there are no remaining passengers from the previous train when doors open, some passengers even run up the escalator (right ⅲ).

(d) By combining these facts, the processing capacity changes irregularly.

The comparison of the outgoing situation between the left side and the right side of the escalator shows as follows:

(a) Comparing the flow rates at the congestion situation between the left side and the right side (left ⅰ and right ⅰ), the right side transports more passengers.

(b) The comparison of the extra time to opening of doors of the next train shows that the extra time of the left side is average 14 seconds shorter at the measured site. This means that while the right side is outgoing, stopping passengers who do not want to walk up generate a queue on the left side. Thus, there are places where escalators are not used effectively. Also, under such a condition, passengers from the subsequent train are added, and the remnant expands in some cases. This is an example of the bottleneck which often occurs at the escalator.

According to the points described above, taking into consideration that the left side of the escalator has a similar passenger's flow as the stairs and that the processing capacity changes irregularly on the right side, we explain in 3.3 how many passengers should be allowed.

3.2.2 Significance of the Maximum Outgoing Passengers for a Station Facility

In consideration of the above, we define that the traffic volumes allowed for a station facility as the 'maximum outgoing passengers for a station facility (per one arrived train)' and consider the following points as the significance.

(a) Traditionally, the design of a station facility in Japan is based on 'average traffic volumes at the peak time' and is calculated so that the station facility is able to cope easily with average traffic volumes per train during the peak 30 minutes. However, when looking at the passenger's flow per train more closely, the processing capacity of the station facility drops and the remnant of passengers expand. If such conditions are allowed to continue, it puts passenger's security at risk and causes train delays.

(b) In addition, as a way to decide the design capacity for transport facilities, the 30^{th} highest hourly volumes are used for the roads in Japan, taking economic efficiency into consideration. On the other hand, for railways, if the station facility loses its capacity, it causes the excessive overcrowding at the stairs/escalators and in front of the ticket gates, as well as an increased risk of passengers falling off the platform onto the track. Because the overcrowding may put people's lives in danger, it is necessary to set the maximum capacity at the peak time.

As explained above, the view of clearing all passengers of the previous train before the doors of the subsequent train open at the most crowed time is important (Figure 20).

3.3 Analysis of Maximum Outgoing Passengers for a Station Facility

In this section, we explain in detail the result of an analysis of the maximum outgoing passengers for a station facility, the idea of clearing all passengers of the previous train before the doors of subsequent trains open is suggested in 3.2.

First of all, we explain the calculation method of the maximum outgoing passengers, using the stairs as the example. As shown in Figure 15, regardless of the traffic volumes per train, the

flow rate at the congestion situation does not change, and only the time of the congestion situation changes. With this outcome as its base, in this study, we define the light blue area in Figure 21 as the margin of maximum outgoing passengers. With the total of the 'actual traffic volumes' in blue and the 'margin of maximum outgoing passengers' in light blue, the 'maximum outgoing passengers' is defined. We calculated the maximum outgoing passengers at the stairs, and when a graph was created with the maximum outgoing passengers on the ordinate and the headway on the abscissa, it showed a linear regression. Therefore, our hypothesis was confirmed (Figure 22).
Furthermore, for the escalator, the left side was considered the same as the stairs as shown in Figure 23. For the right side, we calculated the probability which the processing capacity decreases and the missing traffic volumes from the actual result. By using the average missing traffic volumes and the probability, adjusting the margin of maximum outgoing passengers, the graph showed the same linear regression as the stairs. Comparing of the maximum outgoing passengers between the left side and the right side of the escalator, the right side transports more passengers even if including the missing traffic volumes. The maximum outgoing passengers is not proportional to the speed of the escalator. The deference is small between the speed of 30m/minute and 40m/minute (Figure 24). The reasons are considered as follows:

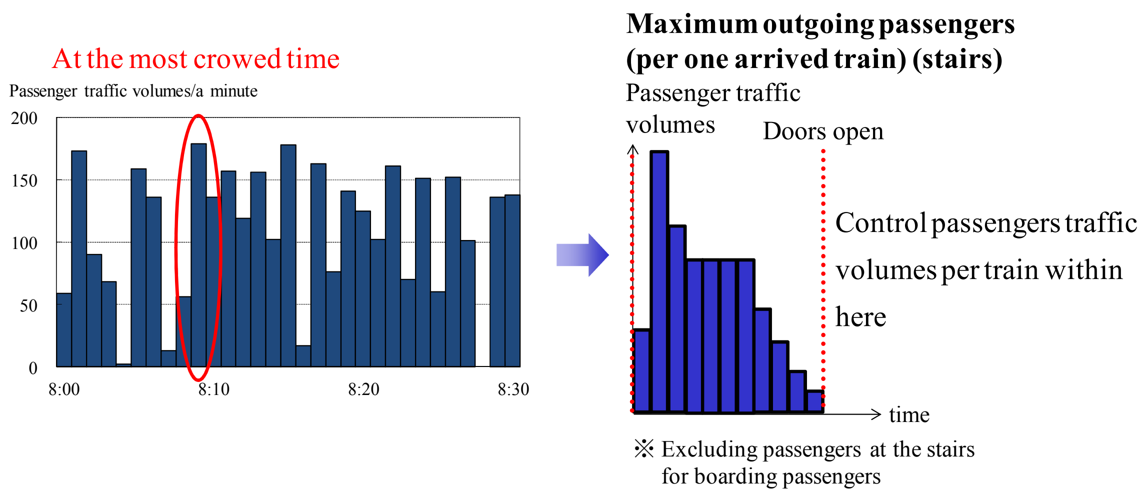


Figure 20 – Significance of the Maximum Outgoing Passengers for a Station Facility (Stairs)

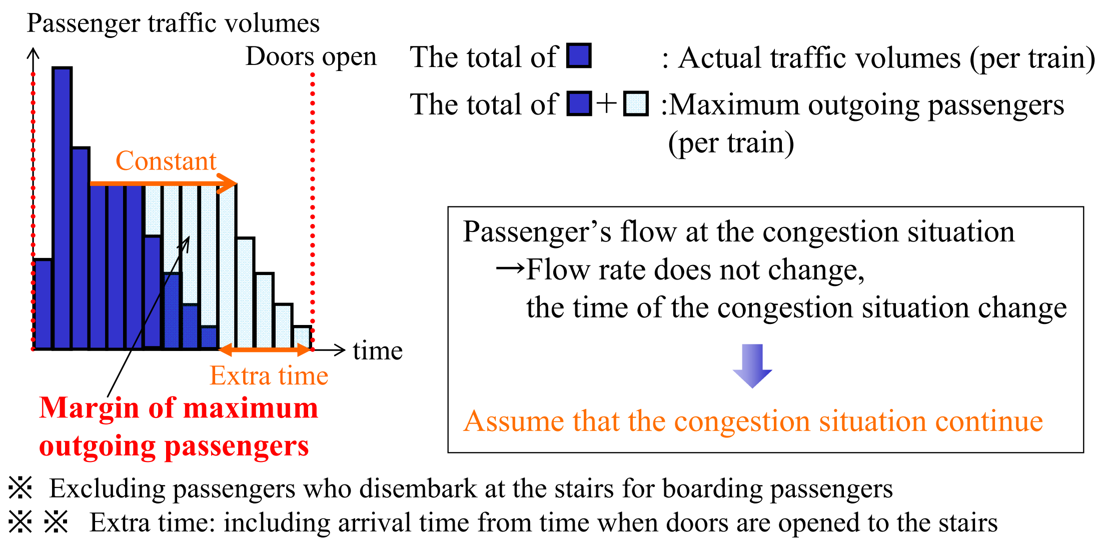


Figure 21 – Calculation Method of the Maximum Outgoing Passengers (Stairs)

(a) The occupation rate of the escalator decreases because people want to keep large gap each other for the safety.
(b) High-speed escalator may be installed in deeper underground station and it becomes longer. Then, more passengers walk slower or stand on the right side.

As for the escalator, it is considered that selecting the left side with less extra time as the bottleneck and calculating the margin of maximum outgoing passengers in order to calculate at how much the escalator can accept the increase of passengers.

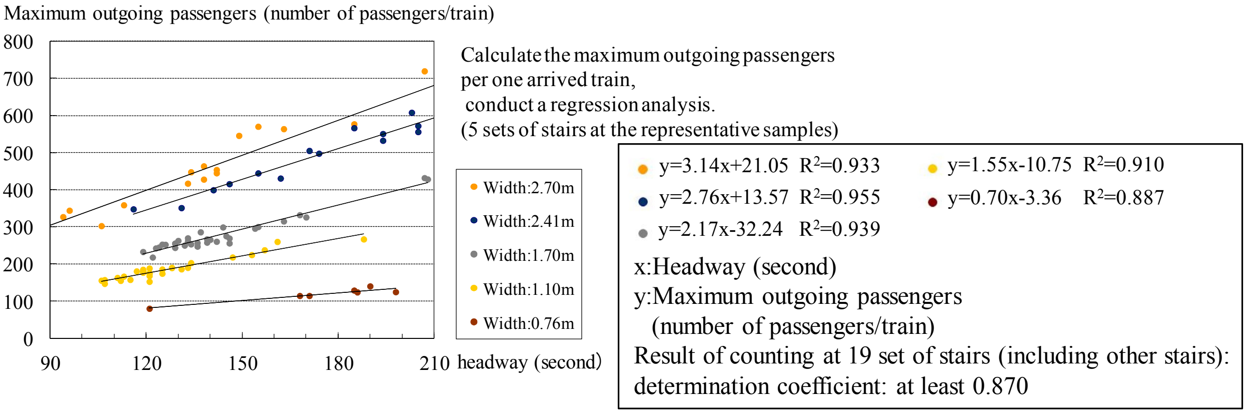


Figure 22 – Change in Maximum Outgoing Passengers per Headway (Stairs)

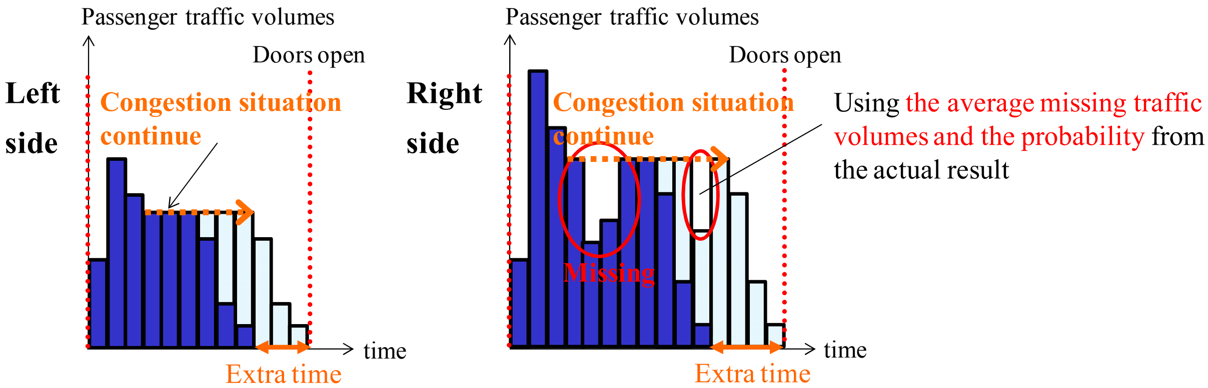


Figure 23 – Calculation Method of the Maximum Outgoing Passengers (Escalator)

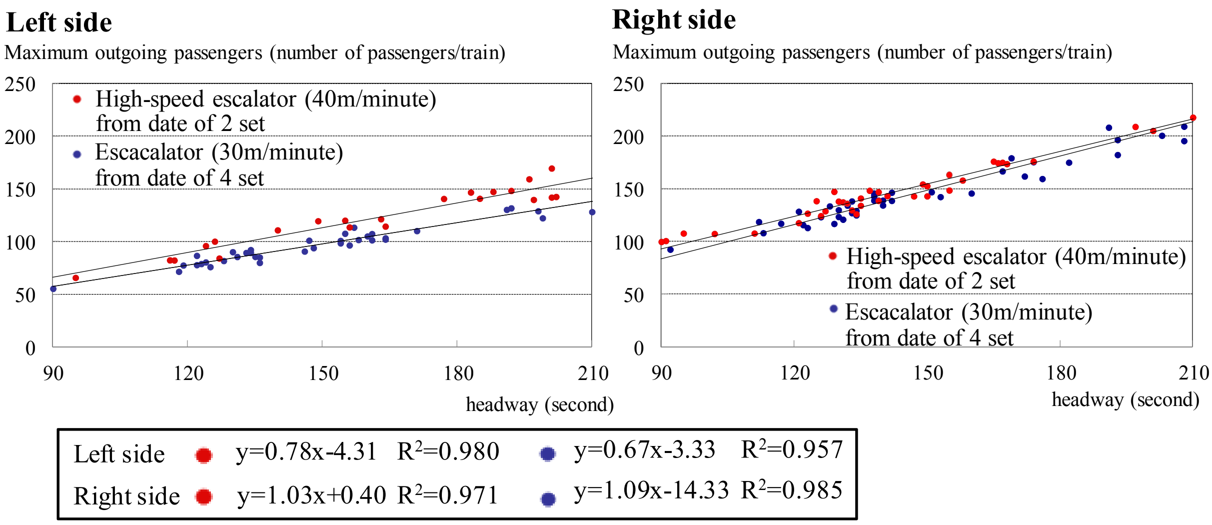


Figure 24 – Change in Maximum Outgoing Passengers per Headway (Escalator)

3.4 Concept of Calculation of the Maximum Outgoing Passengers at a Station

From the above, it is important to accurately analyse the reality of the passenger's flow and grasp how a station can cope with progressing urban development around the station (defined as 'maximum outgoing passengers at a station' in this study). Actually, because there is a difference in passenger traffic volumes depending on the location of the stairs/escalator as shown in the example of Station A in Figure 25, it is necessary to focus on the stairs/escalator as the worst bottleneck. For example, at Station A with the daily number of passengers at approximately 85,900, a large-scale urban development is planned on the east side of the station, and the number of passengers is expected to rapidly increase at each set of stairs/escalators. Therefore, we focused on the passenger's flow from the most crowed train and at the most crowed location and calculated the actual traffic volumes and margin of maximum outgoing passengers. In this study, we assumed that the passenger level increased

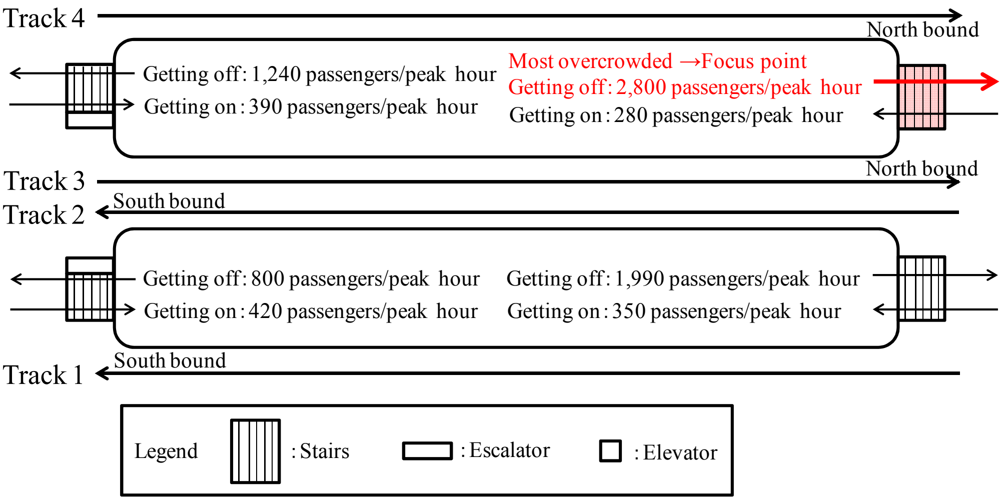


Figure 25 – Boarding and Disembarking Passengers at each the Stair/Escalator at Station A

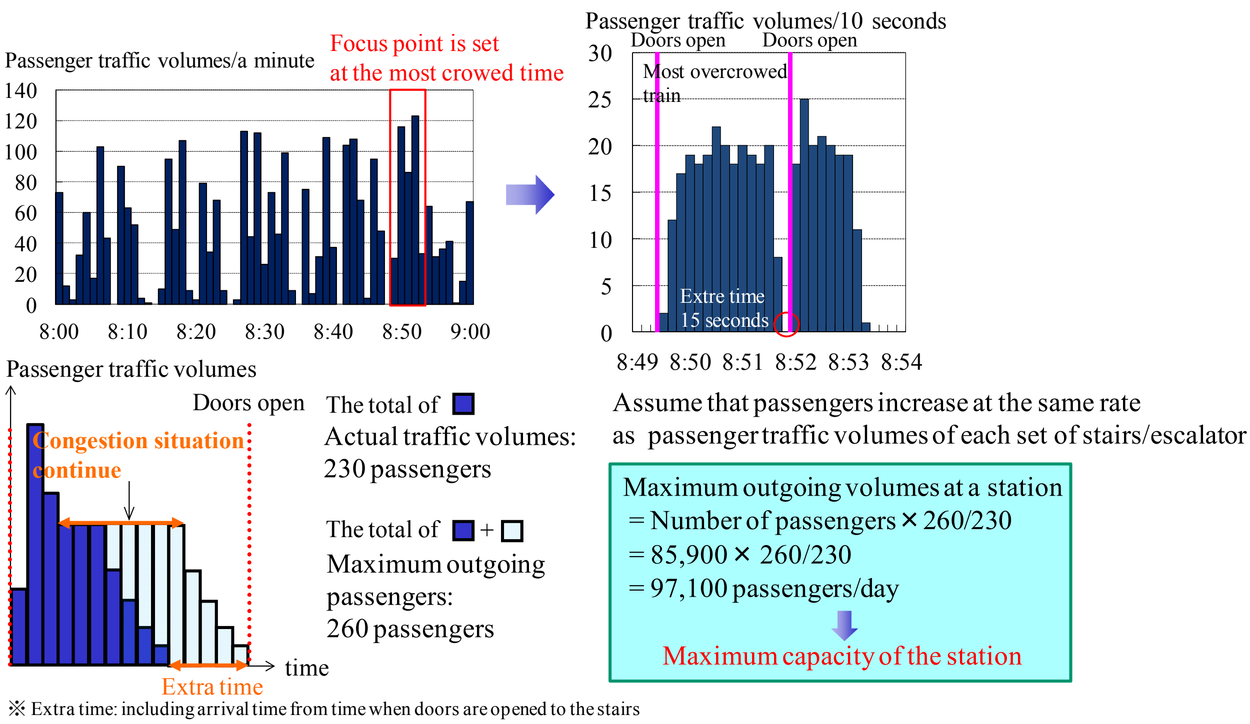


Figure 26 – Image of Calculation Method for Maximum Outgoing passengers at a Station (Station A)

at the same rate as passenger traffic volumes of each set of stairs/escalator. Therefore, we supposed that the maximum number of passengers a station can handle by multiplying the number of passengers with the ratio of the maximum outgoing passengers and the actual traffic volumes per train (Figure 26).

Despite the fact that the subject for the survey was the passenger's flow on the stairs/escalator at the platform only, and the passenger's flow at the stairs/escalator at the concourse/exit of the station was not included, we believe that a similar concept of the stairs/escalator at the platform would apply considering the arrival time from the time when doors are opened to the stairs/escalator at the concourse/exit.

4. SUGGESTION OF MEASURES FOR IMPROVEMENT OF CURRENT LEGAL SYSTEM

In this study, we consider that the 'reasons for serious overcrowding occurring at railway stations in the city centre of Tokyo' lies in the current legal system. Concretely, the issues are as follows: (1) the consistency between the floor area of buildings and the station capacity, (2) from the view of securing the consistency, the railway is not included in the TIA, and (3) the fact that there is no framework to discuss the countermeasures for the overcrowding at stations. Therefore, we discuss what in the current legal system needs to be changed not to generate serious overcrowding beyond the maximum outgoing passengers at a station.

In Japan, until now, station improvements were implemented by railway operators based on the claim that because railway passengers would increase as population increased and would result in higher income for operators, railway operators should improve their station facilities by themselves. However, (1) because population in Japan will decrease from now on, is it appropriate that only railway operators must pay for the improvement of the station facilities which is costly and not profitable? (2) Urban developments have been concentrated around specific stations in Tokyo lately, and it is expected that urban developments will be concentrated in the same areas, the numbers of passengers in these stations will increase in the future. (3) Is it appropriate that the conventional ex-post improvement after the generation of serious overcrowding at the station is implemented? In consideration of the above, we consider that all the related bodies surrounding the railway (not only railway operators, but also government administrators (in both the city division and railway division), urban developers and railway users) need to recognize the above problems and it is necessary to take the countermeasures by all the related bodies surrounding the railway together.

Keeping all of this information in mind, we discuss the following countermeasures to solve the problems. Because of deregulation such as the land use and the FAR of buildings causes a sudden load on the station, and therefore, we consider that it is necessary to preliminarily grasp the maximum outgoing passengers at a station, and to consider the impact on the railways with the TIA and provide a place for the city side and the railway side to discuss the countermeasures for the impact.

If the number of passengers at a station is expected to exceed the maximum outgoing passengers at the station from above analysis, first, it is considered to take software-type countermeasures such as staggered commuting not to exceed the maximum outgoing passengers at the station. Next, if it is impossible to control the situation with software-type countermeasures and some drastic countermeasures are needed, below two countermeasures should be considered. If the city side and the railway side discuss the countermeasures to ease the overcrowding at the station, the discussion should be from the menu listed in Figure 27.

(a) Not allowing further urban development

In accordance with the basic concept of the regulation of the FAR, the government does not approve the urban development and it is required to modify the plan of the urban development such as reconsideration of the urban development in the area where the overcrowding is not generated.

(b) Increasing the station capacity in accordance with urban development

Only (a) is not always the best decision from the view of the urban activation and the increase of international competiveness in the city centre of Tokyo. For this, we suggest, as an approval condition of the urban development, the developer needs to contribute a portion of their profit from the development to improve public facilities (including not only railway facilities but also other public facilities), based on the concept of the TIM [Note 5]. In other words, the method of the urban development should be approved in the case that it contributes to improve the capacity of public facilities.

※ If the station improvement is impossible due to physical restrictions, the government does not allow the urban development (above (a)).

By implementing the station improvement, the ratio of passenger traffic volumes of each set of the stairs/escalator may change, resulting in a change to the location of the bottleneck. Therefore, as shown in Figure 28, it is needed to simulate passenger traffic volumes of each set of the stairs/escalator with a simulation model. And, it is necessary (1) to compare this with the maximum outgoing passengers for the station facility and check that it is within the allowed range, and (2) to check the balance of the location of the station facilities and their capacities (maximum outgoing passengers) to improve them.

Additionally, the financing method stated (b) above might be not enough to procure the cost of the station improvement. Then, with the consideration of the problem that the overcrowding at the station causes train delays, it is considered that part of the funds required for the station improvement is collected by taking extra charge from passengers.

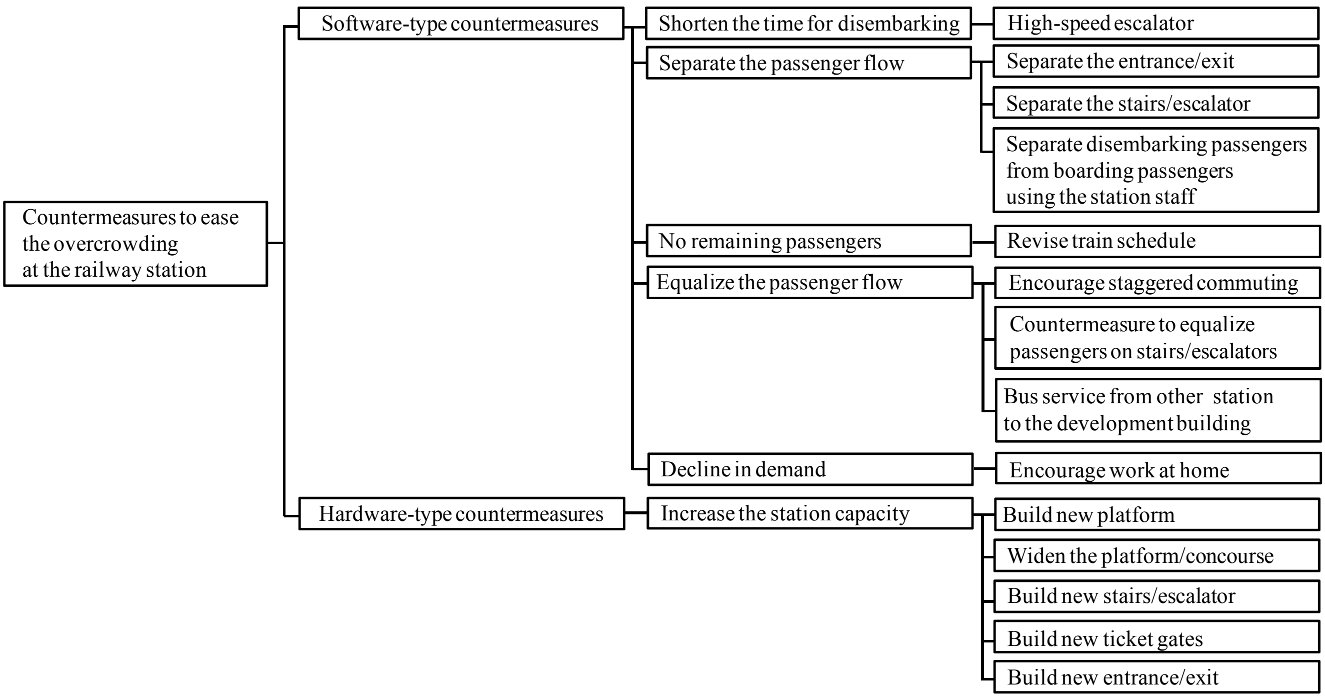


Figure 27 – Countermeasures to Ease the Overcrowding at the Station

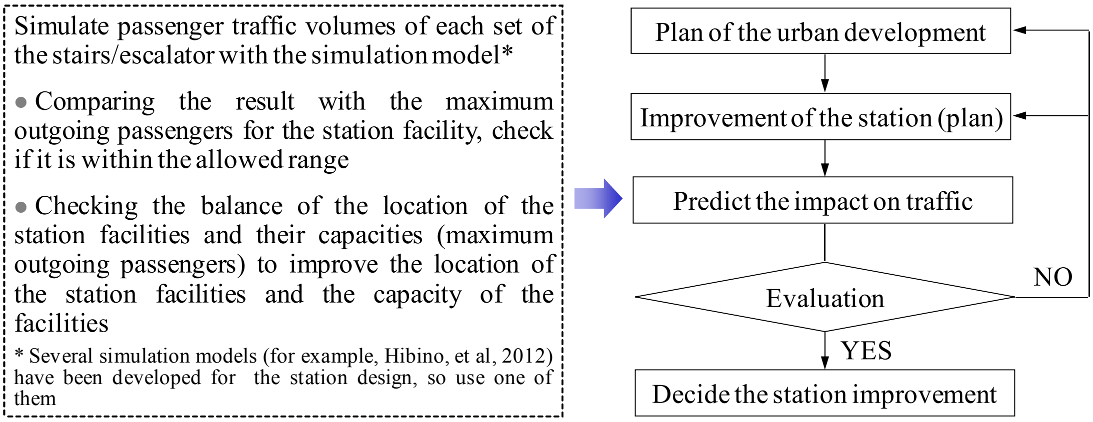


Figure 28 – Process of Reflecting the Result in Planning and Evaluation

5. CONCLUSION

The outcomes of this study are as follows:
(1) Causes of serious overcrowding at railway stations in the city centre of Tokyo were identified and listed.
(2) By developing an original passengers counting system on a mobile phone, we made it possible to measure at random locations the per second flow of outgoing passengers which change moment by moment at the station facility at the peak time's. This had been difficult to measure before this study. We confirmed that this system is useful as a method for fact-finding method.
(3) From the situation analyses of the overcrowding at a station, it became clear that, if disembarking passengers are remaining when doors of the next train are opened, the processing capacity of the station facility drops and the remnant of passengers expand. This shows that it is important to clear all passengers of the previous train before doors of the subsequent train open.
(4) Keeping this (3) in mind, we suggested the 'maximum outgoing passengers for a station facility (per one arrived train)' as how much the station facility can accept in terms of the increase of passengers, and then analysed it concretely.
(5) Based on the above, we suggested what should be improved institutionally to prevent serious overcrowding exceeding the maximum outgoing passengers at a station is recognized as how much the station can accept in terms of the increase of passengers.

Lastly, 'the problem of serious overcrowding at stations accompanied with urban developments' which is occurring earlier in Japan where the modal share of railways is extremely high. While most countries in the world are implementing countermeasures to reduce environmental load by establishing transportation systems which does not rely on automobile transportation by shifting to public transportation modals such as railways. Therefore, especially, in Asian Mega-cities, it is important to pay attention to the issues we have mentioned in this study when constructing a transportation system, which mainly consists of railways.

NOTES

Note 1: Ratio of the total floor area to the site area.

Note 2: Low-rise housing areas, medium- and high-rise housing areas, commercial areas, industrial areas, etc.

Note 3: Open spaces and aisles where pedestrians can use freely.

Note 4: We counted the number of passengers who use the left or right side of a two-people escalator and a one-person escalator at the peak time at 10-minute intervals.

Note 5: The concept of the traffic impact assessment is that people who gained profit from urban development do something to ease the loads on the traffic by using a part of their profit. In fact, several other countries who have introduced a traffic impact assessment, they request the urban developer to pay for the construction of transportation facilities and modify the plan itself (i.e. US Institute of Transportation Engineers, 1992).

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