A STUDY ON THE CHARACTERISTICS OF STATION WITH INTERMODALIZATION OF COAL RAILWAY TRANSPORT AND UNLOADING BASED ON COAL PORT SYSTEM

Guoquan LI	Takeshi CHISHAKI	Wen-Chih HUANG
Doctoral Course	Professor	Doctoral Course
Dept. of Civil Engineering	Dept. of Civil Engineering	Dept. of Civil Engineering
Kyushu University	Kyushu University	Kyushu University
Hakozaki 6-10-1,	Hakozaki 6-10-1,	Hakozaki 6-10-1,
Higashi-ku, FUKUOKA,	Higashi-ku, FUKUOKA,	Higashi-ku, FUKUOKA,
812-81, JAPAN	812-81, JAPAN	812-81, JAPAN
Fax: +81-92-651-0190	Fax: +81-92-651-0190	Fax: +81-92-651-0190

abstract: This paper provides a systematic approach for the analysis on a multi-stage operation system of coal port station with intermodalization of coal railway transport and coal-unloading with the help of simulation. The approach assists designers and planners of station in grasping the fluctuation of each kind of elements, understanding the relationships among influential elements and determining the corresponding scale of each facility at the station system.

Through the discussion on the functions of elements and their fluctuations, this paper clearly gives the queuing characteristics of coal port station and the mutual matching relations among elements in the system.

1. INTRODUCTION

Coal port station is the joint facility of railway and port, where includes many kinds of elements such as yard arrangement, operating services, disposition of facilities, etc. These characteristics of elements and their reciprocal relations have not only influence on coordination between railway transport capacity and unloading system as intermodalization of coal railway transport, but also influence on the reasonable development of coal port and the efficiency of corresponding transport.

In the past studies concerning the design of railway station and arrangement of operation facilities, some queuing models were applied to analyse operation procedure of railway station such as marshalling yard and yard facilities. Petersen (1977) analyzed the yard operation as queuing phenomena and used some queuing models to describe the classification and assembly operations at station yard; and Feng H. *et al* (1987) introduced queuing methods to design the station and to determine the number of tracks at an arrival yard. In these studies, it was assumed that the arrival of train followed the poisson distribution . It is more difficult to use a kind of single queuing model to illustrate a multi-stage, multi-proceduere system. In fact, the investigation on the actual situation of coal port station was reported by Chishaki T. *et al* (1994), in which the coal port station was appointed a multi-stage operation system, relevant arrival of coal train was submited to logarithm normal distribution, and service time of each operation was related to the length of coal train. Empirical studies on the design of port station by Cao (1986) described some types of port station and analyzed the arrangement of operation facilities according to characters of port.

Under the basis of relative studies, a new type of station with the circle unloading tracks and continual coal-unloading tipping plants based on coal port system is proposed in order to improve the transport capacity and operation efficiency in this paper. Its yard arrangement of the station is suitable for the process of unloading operation of coal train and makes an intermodalization of the coal railway transport and coal-unloading at port.

According to the property of station operation, the coal port station generally includes three kind of operations; arrival operation of coal train, coal unloading operation, departure operation of the train of empty stock. However, on the basis of arrival and departure operation sharing the common railway facilities and working teams, the station system can be distinguished into two service systems; sharing system of arrival and departure services, and coal unloading system. The relative elements with queuing features of the station are described by the analysis on the operation procedure of station system and its corresponding state of facilities and trains.

For some similar multi-stage operation systems, relevant studies have been made by Abdou G. *et al* (1993) and Baunach G. R. *et al* (1985) in simulation, and by Bastani (1988) in theoretical analyses. But, the research on the characteristics of coal port station proposed is still preliminary stage. Therefore, a simulation model for more suitable description on the station system is developed. Each kind of composite relationships among different elements at arrival & departure operation system and coal unloading system is respectively formulated by the use of the results of simulation.

Through the discussion on the functions of elements and their flutuations, we can also obtain the queuing characteristics of coal port station and the mutual matching relations among system elements.

2. FACILITY ARRANGEMENT AND RELATIVE OPERATION SYSTEM OF COAL PORT STATION WITH SHARING SYSTEM OF ARRIVAL AND DEPARTURE SERVICES

2.1 Facility Arrangement of Coal Port Station

The facilities at the coal port station are generally composed of station yard, coal unloading plants and circle tracks for joining yard to unloading plants. Yard arrangement and relative operation method at coal port station have not only influence on the coordination between railway transport capacity and unloading system, but also influence on the reasonable development of port capacity.

On the basis of arrival and departure operation sharing the common railway facilities and working teams, the facilities of station system are mainly given as follows:

(l). Arrival-departure yard for the arrival of coal train and the deparure of the train of empty stock.

(2). Unloading lines where tipping plants are set up to unload a full train which is not cut.

(3). Circle tracks between yard system and unloading system.

Its basic yard arrangement is shown as in Fig.1. Coal port station is the joint station of railway and port, where the delivery operation is carried out. The arrangement of station facilities is suitable for the process of unloading operation of coal train. Arrival and departure tracks are arranged in the same yard. That is, arrival-departure yard is transverse arrangement. Arrival tracks of coal train are set up in front of the unloading line, and circle tracks linking up the station yard to the unloading line are set up on the back of tipping plants. After a coal train is unloaded, the train of empty stock will be directly pulled to arrival-departure operation system and enter departure tracks through the circle tracks for departure operating service.

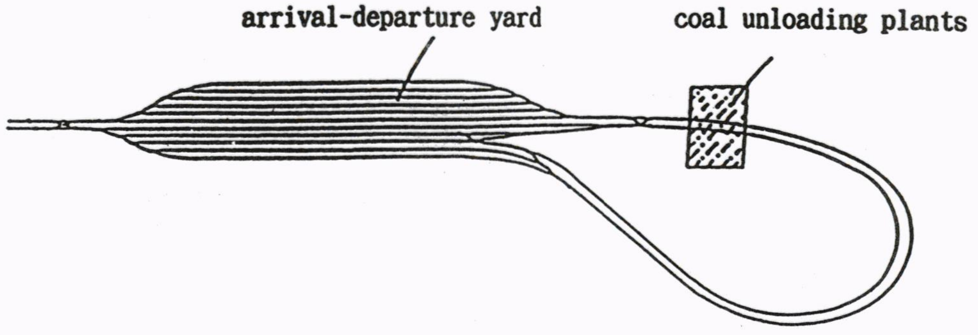

Fig. 1 Facility arrangement of coal port station

2.2 Operation procedure at station system

From Fig. 1, we can obviously describe two operation systems of coal port station including three kind of operations with sharing system of arrival and departure services.

In arrival-departure operation system, two kinds of operations to be called as yard operation are included. After coal train arrives at the arrival track of the station, it needs to handle relative arrival servicing operations before unloading operation such as dropping down the traction locomotive, receiving bow, inspecting the state of coal wagons, checking and delivering the correspondence papers, joining the switching locomotive, etc. Simultaneously, departure operation of the train of empty stock can be carried out, using the same railway facilities and working teams. After the train of empty stock is pulled to departure tracks from the circle track, it needs to handle relative departure servicing operations with the similarity to the content of arrival service of coal train.

In coal unloading system, coal train is pulled to unloading tracks and unloaded by the tipping plants. The train of empty stock is pulled to departure tracks through the circle line.

Through the analysis on the facility arrangement of the station and its operating procedure, the station system can be seen as two independent operation systems; arrival-departure operation system and unloading operation system.

3. ESSENTIAL EXPRESSION OF STATION OPERATION SYSTEM

3.1 State of Trains and Operating Facilities at Station

According to the description of facility arrangement and operating procedure of the station as mentioned-above, the corresponding structure of operating procedure of station system with queuing phenomena can be constructed as in Fig. 2.

The structure of operating procedure at the station system shows the state of facilities or trains at each operation system. These facilities and teams of each operation system are seen

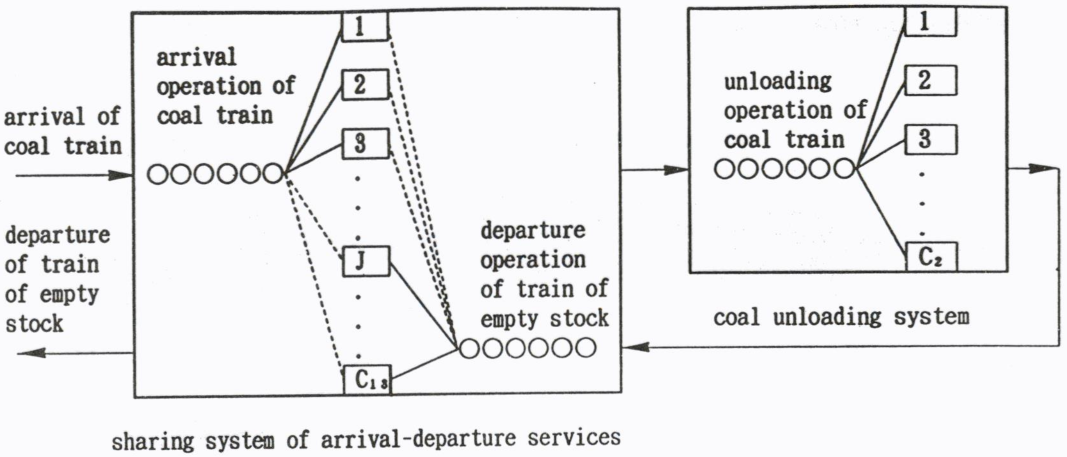

Fig.2 Operation flow of station system with queuing phenomena

as service window, and station yard as the operating and queuing place except unloading. It is assumed that the number of operation facilities and teams at arrival-departure system is C_{13}, and the number of tipping plants at coal unloading system is C_2 at the station system with sharing system of arrival-departure services. When a coal train arrives at coal port station, two kind of states should be considered as follows:

① If former trains arrived are justly carrying out arrival service, or the trains of empty stock are operating for departure service, and all of working teams and facilities are in the working state, the train will have to enter another arrival track to wait for arrival servicing operation, and to form a queuing line (L_{q13}) of arrival-departure operation system.

② If there are any idle facilities and teams at arrival-departure system, after the arrival train enters station yard, the arrival service of coal train can be operated immediately.

Similarly, if any of working teams and facilities for departure service are in the idle state, when the train of empty stock goes back to station yard from unloading line, then its departure service can immediately be handled after the train of empty stock enters station yard. But, if all of working teams and facilities are in the working state, the train of empty stock will have to enter another departure track to wait for departure servicing operation, and to get into the queuing line.

Furtherly, after a coal train has completed arrival operation, its staying state will possibly be as follows:

① If any of unloading tracks are in the idle state, then the train can immediately enter the unloading track for unloading operation.

② If all of tipping plants of unloading track are in the working state, the train will continue to stay arrival yard to wait for unloading operation, and form a queuing line (L_{q2}) of unloading system.

Except trains operating at unloading tracks, all of trains in each state which are operating or waiting for arrival-departure services and waiting for unloading operation will stay in station yard, and one train occupies one railway track of yard. Therefore, to suffice the demands of the arrival-departure operation and unloading operation of station system, the necessary number of yard tracks based on the arrangement as in Fig.1 should be the sum of trains staying in various states as follows:

$$L_{ad}=L_{13}+L_{q2} \qquad \text{(track)} \qquad (1)$$

where L_{ad}: number of yard tracks (track),
L_{13}: number of trains staying in arrival-departure operation system,
L_{q2}: numer of trains staying in yard to wait for coal unloading operation.

3.2 Queuing Elements of Station System

Because station system is seen as operation systems consisting of two independent queuing systems, i.e. sharing system of arrival and departure services and coal unloading ystem, the related elements with queuing features are described as follows:
(1) arrival distribution (arrival density of coal train: n);
(2) distribution of servicing operation time (average service rate: μ_i);
(3) utilization rate of working facilities and teams at arrival-departure system (ρ_{13});
(4) utilization rate of tipping plants at coal unloading system (ρ_2);
(5) number of working facilities and teams at arrival-departure system (C_{13});
(6) number of tipping plants at coal unloading system (C_2);
(7) waiting time of arrival-departure operation system which a train waits for operation (W_{q13});
(8) waiting time of coal unloading system in which a train waits for unloading (W_{q2});
(9) duration at arrival-departure operation system (W_{s13});
(10) duration at coal un loading system (W_{s2});
(11) number of train at arrival-departure system including trains which wait for operation and are in servicing (L_{13});
(12) number of train at coal unloading system including trains which wait for operation and are in unloading service (L_2);
(13) queuing number of trains which wait for service at arrival-departure operation system (L_{q13});
(14) queuing number of trains which wait for unloading at coal unloading system (L_{q2}).

4. RELATIONSHIPS AMONG ELEMENTS WITH QUEUING PHENOMENA

4.1 Some Characters of the Station System

As to the station system, we can see each kind of operation procedure as queuing phenomena. In addition, because there are some particular stochastic features in the station system, the arrival interval time of coal trains is submited to logarithm normal distribution, and service time at each operation is related to the length of coal train and the corresponding residuals can be described as normal distribution. From those as mentioned-above, it is known that the relevant function to describe the characteristics of the station system can not suitably be presented with M/M/C queuing system etc. Therefore, the simulation is developed to investigate the relationships among related elements of station system as shown in Fig. 3.

According to Fig. 2 and 3, we can know the flow concept of station system. On the basis of

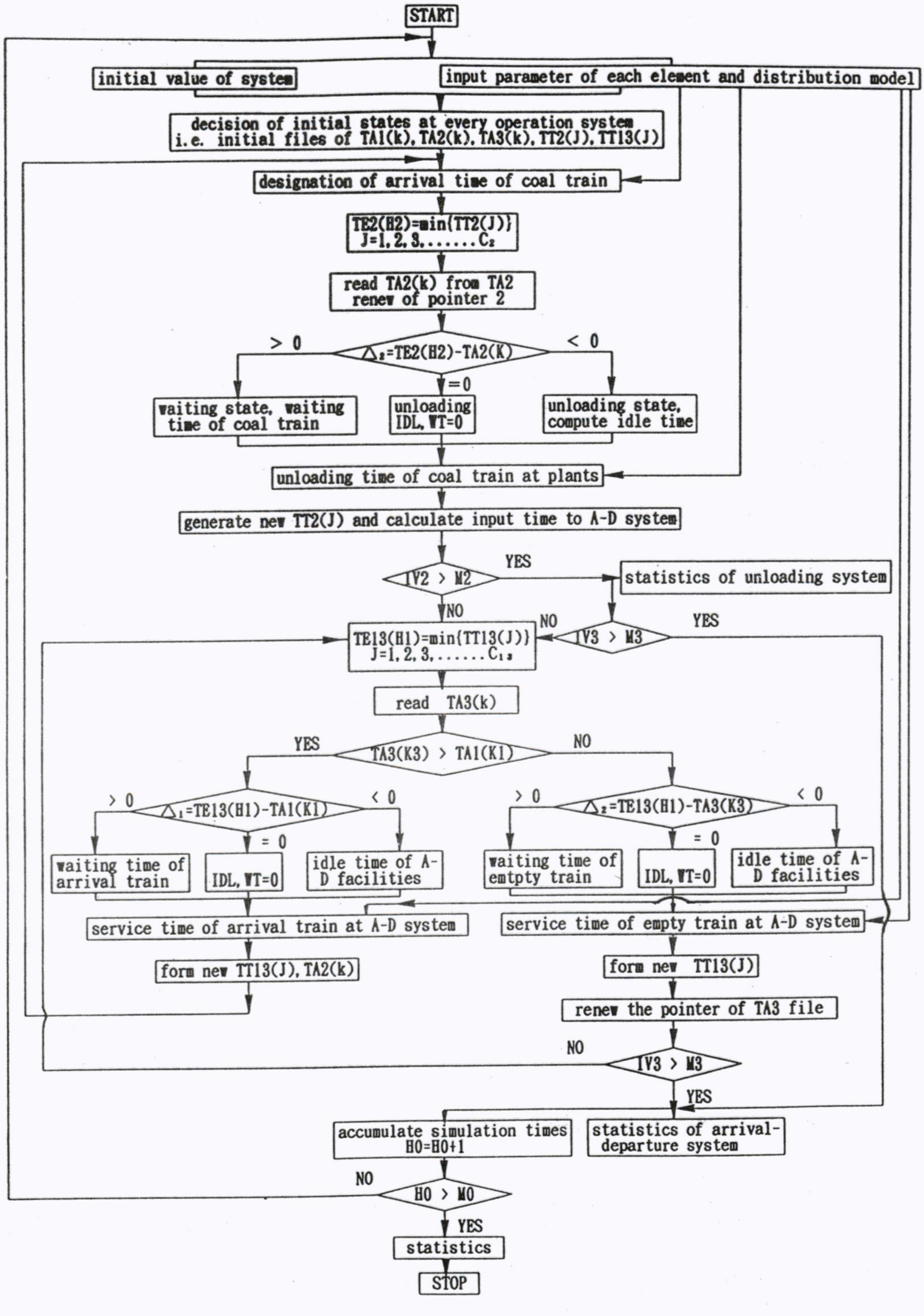

Fig. 3 Simulation model of station system

system flow, the train completing arrival service can immediatly enter unloading track for unloading operation, or continue to stay in yard track to wait for unloading operation. So, if the train completing arrival service is seen as a part of the output of arrival-departure system, then the part becomes the input of coal unloading system. Moreover, the output of coal unloading system is the train completing coal unloading operation and back to yard. The train of empty stock will get departure service at arrival-departure system.

Considering the distribution of train arrival and each kind of operation at station system, we can separately investigate relationships among related elements of sharing system of arrival-departure services and coal unloading system with the help of simulation.

4.2 Description on Arrival-Departure Operation System Sharing the Common Railway Facilities and Working Teams

In order to show the relationships among related elements of arrival-departure operation system clearly, some approximate formulas of queuing system can be obtained by the analyses of correlation regression.

Fig. 4 shows the result of simulation which expresses the relationship between ρ_{13} and W_{q13} based on those conditions as mentioned-above. From the queuing phenomena, the relationship is not only dealing with ρ_{13} and W_{q13}, but also with C_{13}, μ_{13} and n, in which the pattern of relationship changes with the change of C_{13} value. Therefore, we can use Lee-Longton approximate formula for queuing system to describe the relationship among various elements and lead their corresponding parameters into discussion. Through the correlation regression, relevant formulas are obtained as follows:

$$C_{13}=1:\quad W_{q13}=\frac{0.261\rho_{13}^{0.452}(n/\mu_{13})^{4.623C_{13}}}{(C_{13}!(1-\rho_{13})^2)^{0.227}(n)^{3.779}}\quad(\text{hour})\quad(r^2=0.997)\tag{2}$$

$$C_{13}=2:\quad W_{q13}=\frac{0.016\rho_{13}^{1.819}(n/\mu_{13})^{4.323C_{13}}}{(C_{13}!(1-\rho_{13})^2)^{0.331}(n)^{8.101}}\quad(\text{hour})\quad(r^2=0.999)\tag{3}$$

$$C_{13}=3:\quad W_{q13}=\frac{1.046*10^{-2}\rho_{13}^{2.458}(n/\mu_{13})^{2.977C_{13}}}{(C_{13}!(1-\rho_{13})^2)^{0.384}(n)^{8.542}}\quad(\text{hour})\quad(r^2=0.998)\tag{4}$$

$$C_{13}=4:\quad W_{q13}=\frac{1.773*10^{-3}\rho_{13}^{3.321}(n/\mu_{13})^{3.422C_{13}}}{(C_{13}!(1-\rho_{13})^2)^{0.412}(n)^{13.305}}\quad(\text{hour})\quad(r^2=0.991)\tag{5}$$

$$C_{13}=5:\quad W_{q13}=\frac{1.506*10^{-3}\rho_{13}^{4.943}(n/\mu_{13})^{3.406C_{13}}}{(C_{13}!(1-\rho_{13})^2)^{0.478}(n)^{17.025}}\quad(\text{hour})\quad(r^2=0.988)\tag{6}$$

$$C_{13}=6:\quad W_{q13}=\frac{4.594*10^{-3}\rho_{13}^{6.949}(n/\mu_{13})^{3.395C_{13}}}{(C_{13}!(1-\rho_{13})^2)^{0.524}(n)^{21.259}}\quad(\text{hour})\quad(r^2=0.973)\tag{7}$$

From these formulas for the waiting time (W_{q13}), it can be seen that there is sufficient precision to show W_{q13}, because the coefficients of determination in all formulas are over 0.973. In the meantime, the fluctuation's rule of W_{q13} can be found. With the increase of the working teams and facilities (C_{13}) at arrival-departure operation system, the values of W_{q13} change. When C_{13} increases from 1 to 2, 3, W_{q13} decreases very greatly under the

same level of utilization rate (ρ_{13}). But, when C_{13} is over 4, the fluctuation of W_{q13} is very small. Furtherly, when the utilization rate (ρ_{13}) of working teams and facilities is gotten high up, W_{q13} increases. Especially, when $\rho_{13} \geqq 0.8 \sim 0.9$, W_{q13} goes up rapidly.

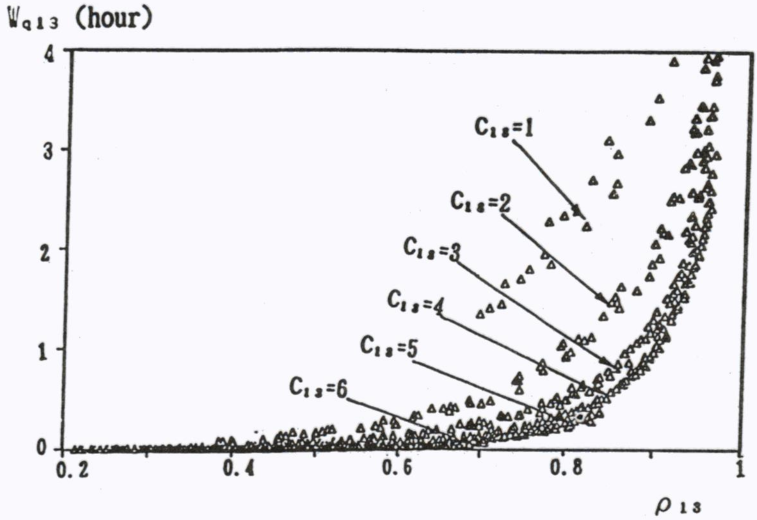

Fig. 4 Waiting time of train at arrival-departure system

Conclusively, from the viewpoint that the service facilities are used efficiently, it is desirable to make the utilization rate higher. Simultaneously, the waiting time of arrival train becomes longer. On the other hand, in order to make W_{q13} down, it is necessary to increase the number of working teams and facilities or to make ρ_{13} low. If W_{q13} is limited within 30 minutes, the corresponding establishment of C_{13} and ρ_{13} should be considered as follows:

if $C_{13}=2$, then $\rho_{13} \leqq 0.6$,
if $C_{13}=3$, then $\rho_{13} \leqq 0.8$,
and if $C_{13}=4$, then $\rho_{13} \leqq 0.85$.

The relationships among W_{s13}, L_{13} and n are shown as in Fig. 5, according to the results of simulation. From these data, the corresponding formula by the regression analysis can be expressed by the following:

$$L_{13} = 1.008(n)^{0.799}(W_{s13})^{0.836} \qquad (\text{ train }) \qquad (r^2=0.996) \tag{8}$$

where $W_{s13}=W_{q13}+1/\mu_{13}$.

From Fig. 5, the value of L_{13} changes with the number of working facilities (C_{13}). That is, when C_{13} is increased on the basis of keeping up in the same level of utilization rate (ρ_{13}), L_{13} will be up. And, when $\rho_{13} \leqq 0.8$, L_{13} will linearly increase with the change of ρ_{13}. But, when $\rho_{13} \geqq 0.8$, L_{13} will exponentially go up.

Furtherly, we can obtain some another descriptions for the arrival-departure operation system as in the following:

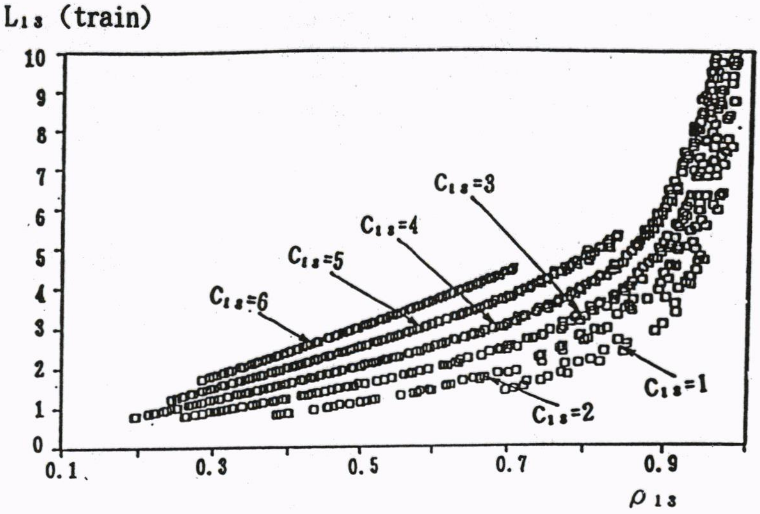

Fig. 5 Trains staying at arrival-departure system

(a) relationship formula among W_{q13}, L_{q13} and n

$$L_{q13} = 0.891(n)^{0.708}(W_{q13})^{0.955} \qquad (\text{train}) \qquad (r^2=0.963) \tag{9}$$

(b) relationship formula among ρ_{13}, C_{13}, μ_{13} and n

$$\rho_{13} = \frac{0.807(n)^{0.730}}{(C_{13}\mu_{13})^{0.832}} \qquad (r^2=0.986) \tag{10}$$

4.3 Description on Unloading Operation System

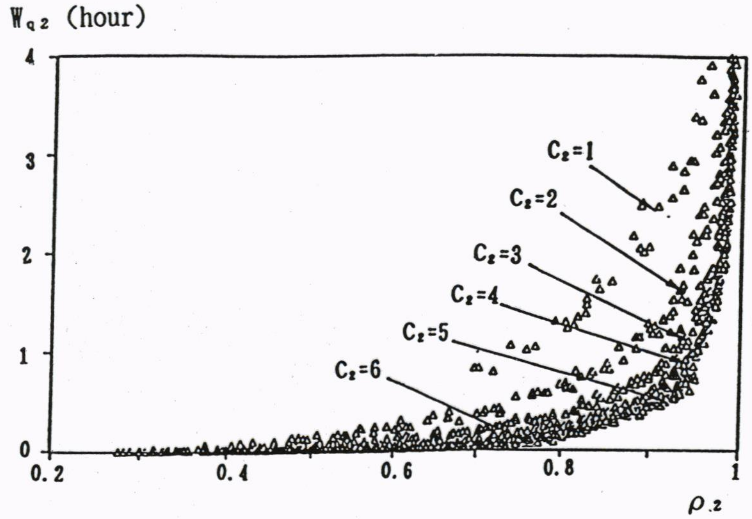

Fig. 6 Waiting time of train at coal unloading system

Just as the same as the description of arrival-departure operation system, there are also queuing characteristics in coal unloading system. The plot in Fig. 6 shows the relationships among waiting time for unloading (W_{q2}), the number of operation facilities (C_2), its corresponding service rate (μ_2), and arrival density of coal train (n). Using the correlation regression, the relevant formulas among ρ_2, W_{q2}, C_2, μ_2 and n can be presented as follows:

$C_2=1$: $$W_{q2} = \frac{1.29\rho_2^{1.879}(n/\mu_2)^{0.583C_2}}{(C_2!(1-\rho_2)^2)^{0.15}(n)^{0.090}}$$ (hour) (r^2=0.984) (11)

$C_2=2$: $$W_{q2} = \frac{0.235\rho_2^{1.424}(n/\mu_2)^{0.953C_2}}{(C_2!(1-\rho_2)^2)^{0.153}(n)^{0.678}}$$ (hour) (r^2=0.998) (12)

$C_2=3$: $$W_{q2} = \frac{3.996*10^{-2}\rho_2^{1.262}(n/\mu_2)^{1.0c^2}}{(C_2!(1-\rho_2)^2)^{0.187}(n)^{1.350}}$$ (hour) (r^2=0.996) (13)

$C_2=4$: $$W_{q2} = \frac{9.014*10^{-3}\rho_2^{2.105}(n/\mu_2)^{1.073C_2}}{(C_2!(1-\rho_2)^2)^{0.157}(n)^{2.312}}$$ (hour) (r^2=0.994) (14)

$C_2=5$: $$W_{q2} = \frac{2.767*10^{-3}\rho_2^{2.609}(n/\mu_2)^{1.029C_2}}{(C_2!(1-\rho_2)^2)^{0.186}(n)^{2.963}}$$ (hour) (r^2=0.977) (15)

$C_2=6$: $$W_{q2} = \frac{1.329*10^{-3}\rho_2^{2.896}(n/\mu_2)^{1.013C_2}}{(C_2!(1-\rho_2)^2)^{0.311}(n)^{3.768}}$$ (hour) (r^2=0.972) (16)

Because all of their coefficients of determination are over 0.972, there is no problem in the precision of these formulas. Also, W_{q2} changes with C_2 and ρ_2. Especially, the changes of W_{q2} are very great with C_2=1, 2, 3. But, when $C_2 \geqq 4$, the changes are gradually going small. Furtherly, when $\rho_2 \geqq 0.95$, W_{q2} goes up sharply.

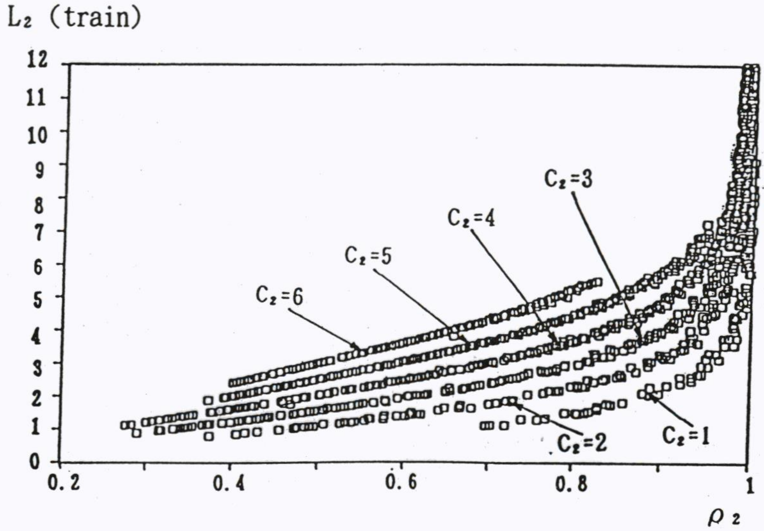

Fig. 7 Trains staying at coal unloading system

Similarly, the relationship among the number of staying trains (L_2), staying duration of coal train (W_{s2}) in coal unloading system, and arrival density of coal train (n) can be shown as in Fig. 7, and the corresponding formula is found as follows:

$$L_2 = 1.290(n)^{0.767}(W_{s2})^{0.661} \qquad \text{(train)} \qquad (r^2=0.996) \qquad (17)$$

where $W_{s2}=W_{q2}+1/\mu_2$.

If $\rho_2 \leqq 0.8$, the number of coal trains (L_2) staying at coal unloading system will increase linearly with the increment of ρ_2, and if $\rho_2 \geqq 0.8$, the value of L_2 increases rapidly.

In the same time, the relationship among W_{q2}, L_{q2} and n can be estimated as follows:

$$L_{q2} = 1.308(n)^{0.685}(W_{q2})^{1.095} \qquad \text{(train)} \qquad (r^2=0.940) \qquad (18)$$

Moreover, the formula among ρ_2, μ_2 and n can be found in the following:

$$\rho_2 = \frac{0.894(n)^{0.656}}{(C_2\mu_2)^{0.777}} \qquad (r^2=0.982) \qquad (19)$$

All of these formulas as mentioned-above can properly express the queuing characteristics of coal port station which is a queuing system with a multiple-stage and multiple-procedure operation. And also, these formulas have higher precision because all of their coefficients of determination are greater than 0.94.

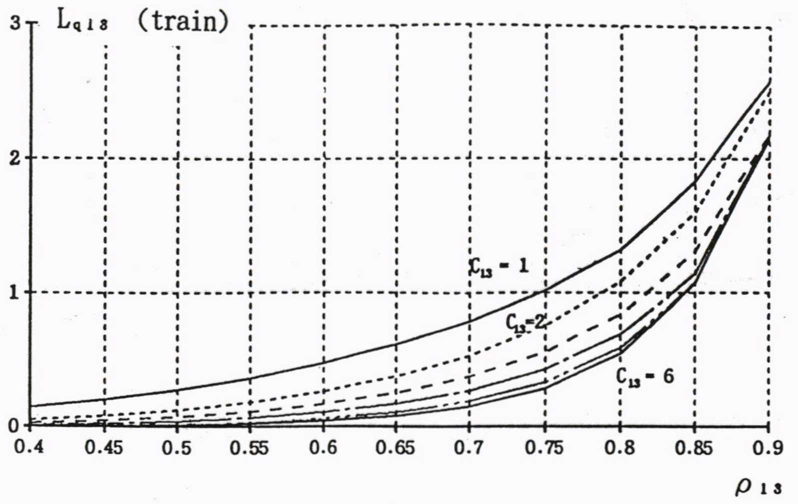

Fig. 8 Queuing trains at arrival-departure system based on ρ_{13}

5. FURTHER DISCUSSION ON THE CHARACTERISTICS OF STATION SYSTEM

Queuing length is an important element in queuing system which impacts system procedure very strongly. Owing to two kind of operation system at coal port station, we will respectively discuss the relevant property of queuing length with arrival-departure system and coal unloading system.

5.1 Some Property of Queuing Length at Arrival-Departure System

At arrival-departure operation system, from Eq. (9), we can know the relationship among queuing length (L_{q13}) of coal train for arrival or departure services, waiting time (W_{q13}) and arrival density of coal trains (n). But, because there is a strong connection between L_{q13} and ρ_{13} that is learned from the investigation on queuing system, it is important that the fluctuation of L_{q13} is analysed in more details in order to understand the characteristics of arrival-departure operation system.

The relationships between L_{q13} and ρ_{13} are shown as in Fig. 8. Certainly, at the same number of working facilities and teams (C_{13}), the queuing length (L_{q13}) will exponentially changes with the increase of ρ_{13}.

Similarly, the corresponding relationships between C_{13} and L_{q13} can be found as in Fig. 9. At the same level of utilization rate (ρ_{13}), L_{q13} will go down with the increase of C_{13}. Furtherly, when ρ_{13} changes from 0.8 to 0.9, the increasing degree of L_{q13} will be very great.

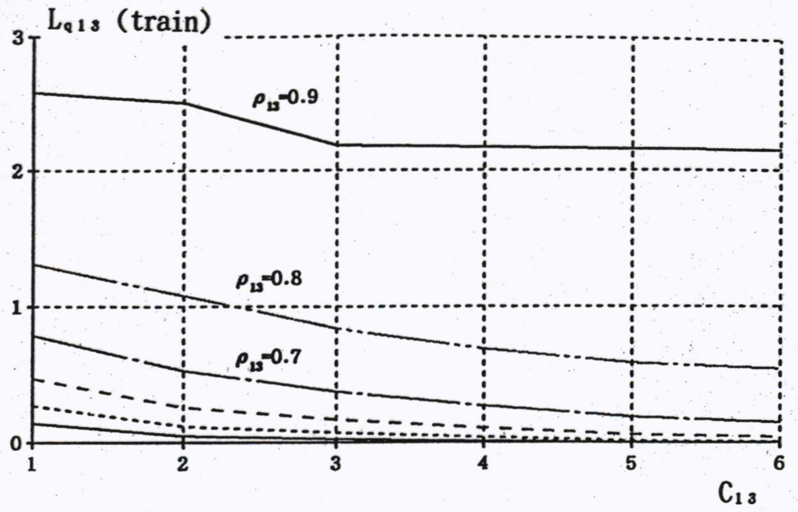

Fig. 9 Queuing trains at arrival-departure system based on C_{13}

5.2 Some Property of Queuing Lenth at Coal Unloading System

Queuing length at coal unloading system not only represents the property of a queuing element, but also plays an important role in the planning of yard system , because the trains in queuing length will stay at station yard.

Similarly, on the queuing length (L_{q2}) at coal unloading system, we can investigate its property as the same as arrival-departure operation system. Eq. (18) shows the relationships among L_{q2}, W_{q2} and *n*. Here, we will give more consideration to the connection between L_{q2} and ρ_2, or L_{q2} and C_2, because this kind of connection can strongly influence the planning of station system.

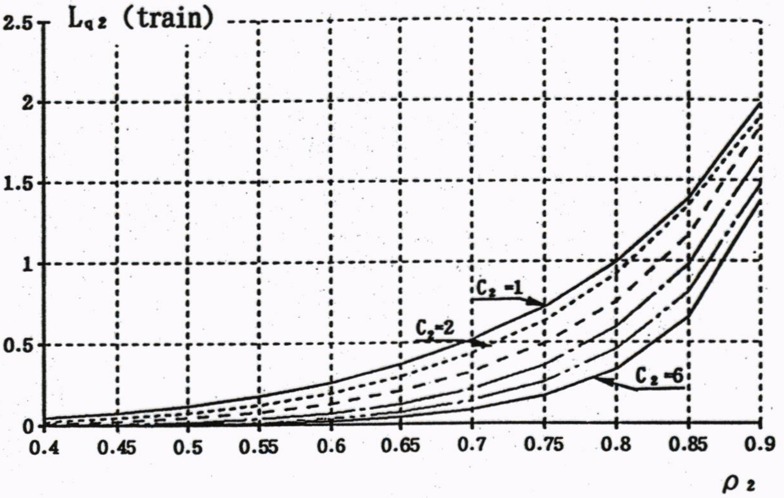

Fig. 10 Queuing trains at coal unloading system based on ρ_2

The relationships between L_{q2} and ρ_2 are shown as in Fig. 10. It is seen that L_{q2} increases rapidly with the increase of ρ_2 at the same value of C_2.

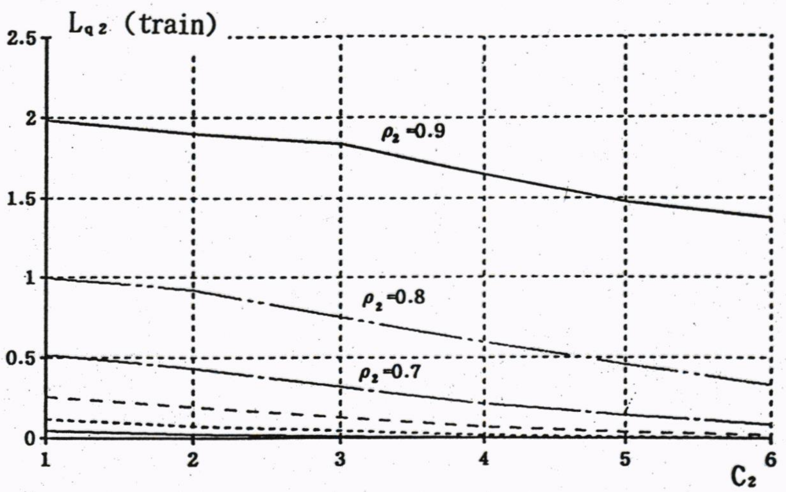

Fig. 11 Queuing trains at coal unloading system based on C_2

On the other hand, Fig. 11 shows the relationships between L_{q2} and C_2. From these relationships, it is found out that L_{q2} will gradually decrease with the increase of C_2, and the increasing degree of L_{q2} will become greater in accordance with the increase of ρ_2.

5.3 Establishment of Station Facilities Based on Queuing Characteristics

We can use queuing characteristics of coal port station in order to establish corresponding station facilities.

Eq.(1) gives the necessary number of tracks in yard to meet the demands of station system. The determination of yard scale should be combined with the relation among queuing elements of every operation system such as arrival density of coal train which reflects the railway transport capacity, service facilities, and utilization rate of every facility. The queuing characteristics of coal port station system as mentioned-above will assist the understanding of the mutual matching relation among station elements. When the arrival density of coal train is up to a certain level, relevant number of operation facilities should be established under the consideration of their effectiveness.

Owing to these consideration on the station system, we can decide the necessary scale of yard, the number of arrival-departure service facilities, and the number of unloading plants at the station. Simultaneously, some important indices including staying duration and utilization rate of every operation facility can be obtained.

Table 1 Matching Relationship among Facilities at Coal Port Station

arrival density of coal train (train/hour)		0.5	1.14	1.5	2.37	2.8	3.1
arrival-departure operation system	service facilities	1	2	2	3	4	4
	numbers of stay trains (train)	1.466	2.023	3.347	4.006	3.573	4.053
	utilization rate of facility	0.7	0.7	0.85	0.85	0.75	0.8
	stay duration (hour)	2.932	2.025	2.869	2.287	1.717	1.835
unloading operation system	service facilities	1	2	3	4	4	5
	numbers of queuing trains (train)	1.387	1.345	0.492	0.594	1.651	0.457
	utilization rate of facility	0.85	0.85	0.75	0.8	0.9	0.8
	stay duration (hour)	3.283	2.607	1.98	1.949	2.309	1.855
duration staying at station (hour)		6.215	4.632	4.849	4.236	4.026	3.69
necessary yard scale (track)		4	5	5	6	6	6

Table 1 is the calculating results of station system based on queuing characteristics. It shows the matching relation among station elements on the basis of a certain capacity of railway tranport. For example, when the arrival density of coal train is 1.5 trains/hour, the least scale of station yard is assigned with 5 tracks to match the railway transport capacity. Correspondingly, the service facilities and working teams at arrival-departure operation system should be established as 2, and the unloading plants as 3. In this case, relevant utilization rates of operation facilities are ρ_{13}=0.85 and ρ_2=0.75, respectively. The total duration of coal train staying at coal port station is 4.849 hours.

Reversely, if there are 6 tracks of yard scale at the station, the service facilities at arrival-departure operation system are C_{13}=4, and unloading plants are C_2=4, the station is able to meet the demand of railway transport capacity which arrival density of coal train is 2.8 train/hour. And in the conditions, the utilization rates of operation facilities are ρ_{13}=0.75 and ρ_2=0.9, respectively. The total duration of train staying at the station is less than 5 hours.

All of those as mentioned-above reflects the systematic coordinating relationships among various elements to be solved by the use of the approach in this study with queuing characteristics of station system.

6. CONCLUSIONS

The railway station is a kind of complicate system with queuing features. Although the studies on general station system were achieved through using some models of queuing system such as M/M/C, it is still in initial stage that the research on the multi-stage, multi-procedure operation system because of more complexity in the construction of system. This paper gives a new type of station system with intermodalization of coal railway transport and unloading on the basis of arrival and departure operation sharing the common railway facilities and working teams. Therefore, the understanding of its basic characteristics based on queuing phenomena is of importance for the design of coal port station. The intermodalization of coal railway transport and unloading is aimed at forming a kind of coordination between the railway transport capacity and unloading system in order to increase operation efficiency of station. And, this kind of coordination relationships are realized by the assignment of operation facilities matching with each other among operation systems at coal port station.

According to the thought as mentioned-above, we synthetically analysed every operation system of coal port station with the help of simulation. In the meantime, some relevant formulas for the description on queuing characteristics of the station system were found in this paper. In addition, the relationships among various queuing elements were discussed in details for assisting the consideration in establishment of station facilities.

Finally, using these queuing characteristics, we found out the matching relationships among the railway transport capacity, system facilities and yard scale (number of tracks) under a certain level of utilization rate of every operation facilities.

As a kind of general queuing phenomena, this study is of universal significance to discuss on the similar problem of another system.

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