DETERMINATION OF YARD SCALE AND RELEVANT OPERATION FACILITIES AT STATION

Guoquan LI
Assistant Professor
Department of Civil Engineering
Kyushu University
Hakozaki 6-10-1,
Higashi-ku, FUKUOKA,
812-81, JAPAN
Fax: +81-92-642-3306

Takeshi CHISHAKI
Professor
Department of Civil Engineering
Kyushu University
Hakozaki 6-10-1,
Higashi-ku, FUKUOKA,
812-81, JAPAN
Fax: +81-92-642-3306

abstract : This paper discusses an optimum approach for the determination of yard scale and relevant operation facilities at coal port station according to the feature of operation system. Using the research conclusions in our previous works about the characteristics of station system with sharing system of arrival and departure service, a systematical nonlinear programming model with multiple-purpose is proposed, and relevant method for determining the yard scale and relevant operation facilities in the system according to the changes of traffic volume are synthetically studied.

1. INTRODUCTION

Improvement and determination of yard scale and relevant operation facilities of station are very important subject with the increase of traffic volume of rail transport. For the coal rail transport system, the station based on coal port, which is called as coal port station, is a very complicated system as the joint of railway and port, where is composed of multi-stage operation subsystems with circle unloading tracks and continual coal-unloading tipping plants including many kinds of impact elements such as yard arrangement, operation service distribution, disposition of facilities etc. Every operation subsystem in the station system is able to be described with queuing characteristics, and some elements have stochastic property, in which corresponding characteristics will change with different working ways of arrival and departure services for train. And these characteristics of elements and their reciprocal relations have a great influence on not only the coordination between railway transport capacity and unloading system, but also the reasonable development of coal port and the efficiency of corresponding transport.

In the previous works of T. CHISHAKI *etal* (1995), the characteristics of station system with sharing system of arrival and departure service had been systematically discussed, and many relation formulas with queuing phenomena were constructed. In this study, using the research conclusions, authors trys to provide an optimum approach for solving the planning of station system in order to assist designers and planners in decision-making procedure for the improvement and determination of rail tracks at coal port station and relevant operation facilities according to the feature of operation system. A systematical nonlinear programming model with multiple-purpose is proposed, and relevant method for determining the yard scale and relevant operation facilities in the coal port system according to the changes of traffic volume are synthetically studied.

On the mathematical model, we lead the concept of fuzzy membership function to deal with every objective function, and present a kind of fuzzy algorithm with the help of simulation to find the compromising solutions among different purposes. Stochastic characteristics about each kind of solutions are investigated.

As an practical application of our proposed model, some alternatives to decide operation facilities and yard tracks are studied in accordance with actual changes of traffic volume of coal transport. In the meantime, some important indexes to evaluate the station system such as staying duration of train at station system and utilization rate of operation facilities are stochastically discussed.

2. STRUCTURE OF COAL PORT STATION AND RELEVANT SYSTEM CHARACTERISTICS

2.1 Structure of Coal Port Station

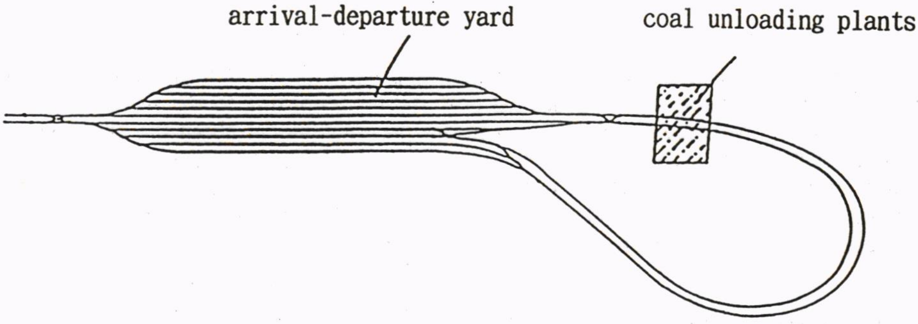

Fig. 1 Station structure based on the coal port

Fig. 1 shows the station structure based on the coal port. It is composed of the following facilities:
(1). 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, where link up the unloading line to station yard.

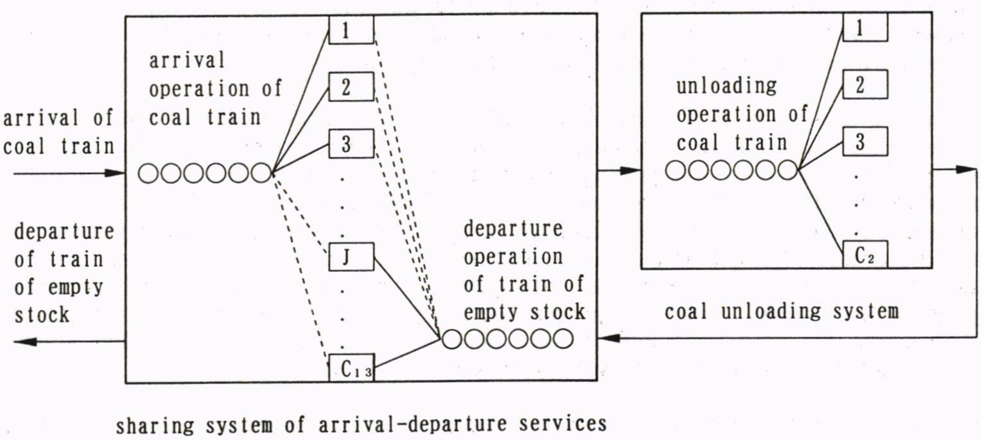

Fig. 2 Operation procedure of coal port station

On the basis of arrival and departure operation service sharing the common railway facilities and working teams, arrival and departure tracks are allocated in the same yard. Yard of station 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. And, station yard is not only the staying place for arrival and departure trains, but also for the waiting trains for coal unloading.

From the arrangement of station facilities, the corresponding procedure of station operation system can be described as Fig. 2. It is obvious that the station system can be divided into two operation subsystems including three kind of operations with sharing system of arrival and departure services.

In arrival-departure operation subsystem, 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.

On the other hand, according to the investigation on the actual situation of coal port station by Chishaki T. *et al* (1994), 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 and other factors.

2.2 Characteristics of Station System

Because there are some particular stochastic features of elements at station system, relevant function to describe the queuing characteristics of the system can not suitably be presented with M/M/C queuing system etc. Through system simulation of station, the queuing relationships among related elements can be obtained in the following.

2.2.1 Description on Arrival-Departure Operation Subsystem

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 using the results of simulation as follows:

1. Waiting time of train at arrival-departure operation subsystem

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

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

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

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

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

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

Where n : arrival density of coal train with stochastical feature;
μ_{13}: service rate with stochastical feature;
ρ_{13}: utilization rate of working facilities and teams at arrival-departure system ;
C_{13}: number of working facilities and teams at arrival-departure system;
W_{q13} : waiting time of arrival-departure operation subsystem which a train waits for operation.

From these formulas, the waiting time of coal train at arrival-departure subsystem changes with the increase of the working teams and facilities (C_{13}). 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. Therefore, when $C_{13}\geqq 6$, the relevant changing curve can be approximately replaced by formula (6).

2. Relationship formula about staying trains at arrival-departure subsystem

$$L_{13}=1.008(n)^{0.799}(W_{s13})^{0.836}$$ (train) (r^2=0.996) (7)

where $W_{s13}=W_{q13}+1/\mu_{13}$, duration at arrival-departure operation subsystem ;
L_{13}: numbers of trains staying at arrival-departure system including trains which wait for operation and are in servicing.

Furtherly, we can obtain some another descriptions for the operation subsystem in the following.

3. Relationship formula about queuing train

$$L_{q13}=0.891(n)^{0.708}(W_{q13})^{0.955}$$ (train) (r^2=0.963) (8)

where L_{q13} : queuing number of trains which wait for service at arrival-departure operation subsystem.

4. Relationship formula about utilization rate

$$\rho_{13}=\frac{0.807(n)^{0.730}}{(C_{13}\mu_{13})^{0.832}}$$ (r^2=0.986) (9)

2.2.2 Description on Unloading Operation Subystem

Just as the same as the description of arrival-departure operation subsystem, there are also queuing characteristics at coal unloading subsystem as follows.

$$C_2=1: \quad W_{q2} = \frac{1.29\rho_2^{1.879}(n/\mu_2)^{0.583C_2}}{(C_2!(1-\rho_2)^2)^{0.15}(n)^{0.090}} \quad \text{(hour)} \quad (r^2=0.984) \quad (10)$$

$$C_2=2: \quad W_{q2} = \frac{0.235\rho_2^{1.424}(n/\mu_2)^{0.953C_2}}{(C_2!(1-\rho_2)^2)^{0.153}(n)^{0.678}} \quad \text{(hour)} \quad (r^2=0.998) \quad (11)$$

$$C_2=3: \quad W_{q2} = \frac{3.996*10^{-2}\rho_2^{1.262}(n/\mu_2)^{1.0C_2}}{(C_2!(1-\rho_2)^2)^{0.187}(n)^{1.350}} \quad \text{(hour)} \quad (r^2=0.996) \quad (12)$$

$$C_2=4: \quad W_{q2} = \frac{9.014*10^{-3}\rho_2^{2.105}(n/\mu_2)^{1.073C_2}}{(C_2!(1-\rho_2)^2)^{0.157}(n)^{2.312}} \quad \text{(hour)} \quad (r^2=0.994) \quad (13)$$

$$C_2=5: \quad W_{q2} = \frac{2.767*10^{-3}\rho_2^{2.609}(n/\mu_2)^{1.029C_2}}{(C_2!(1-\rho_2)^2)^{0.186}(n)^{2.963}} \quad \text{(hour)} \quad (r^2=0.977) \quad (14)$$

$$C_2\geqq 6: \quad W_{q2} = \frac{1.329*10^{-3}\rho_2^{2.896}(n/\mu_2)^{1.013C_2}}{(C_2!(1-\rho_2)^2)^{0.311}(n)^{3.768}} \quad \text{(hour)} \quad (r^2=0.972) \quad (15)$$

and,

$$L_2 = 1.290(n)^{0.767}(W_{s2})^{0.661} \quad \text{(train)} \quad (r^2=0.996) \quad (16)$$

in the same time,

$$L_{q2} = 1.308(n)^{0.685}(W_{q2})^{1.095} \quad \text{(train)} \quad (r^2=0.940) \quad (17)$$

and moreover,

$$\rho_2 = \frac{0.894(n)^{0.656}}{(C_2\mu_2)^{0.777}} \quad (r^2=0.982) \quad (18)$$

Where ρ_2 : utilization rate of tipping plants at coal unloading subsystem ;
C_2: number of tipping plants at coal unloading subsystem ;
W_{q2} : waiting time of coal unloading system in which a train waits for unloading;
W_{s2}: duration at coal un loading system ($W_{s2}=W_{q2}+1/\mu_2$);
L_2: numbers of trains staying at coal unloading subsystem including trains which wait for operation and are in unloading service;
L_{q2}: queuing numbers of trains which wait for unloading at coal unloading subsystem.

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

Furtherly, At the station 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, the necessary number of yard tracks based on the arrangement as mentioned-above should be the sum of trains staying in various states as follows:

$$L_{ad}=L_{13}+L_{q2} \quad \text{(track)} \qquad (19)$$

where L_{ad}: number of yard tracks (track).

3. MODEL FOR SYSTEMATICAL OPTIMIZATION

Based on the concepts and relative meaning of optimization, the main purpose optimizing a system is to obtain reasonable planning and design of correspondence system, or to form relevant alternatives. Relevant objective functions and constraints can be found and discussed in details, using the characteristics of queuing system and mutual relationships among elements.

3.1 Objective Functions

The general goals which is pursued by designers and planners of station are to make the utilization rate of station facilities as great as possible, and in the meantime, reduce staying duration of train at station as far as possible. Therefore, in this study, the objective functions can be considered as maximizing the utilization rate of station facilities and minimizing the staying duration of train.

1. Utilization rate of system facilities at station

On the background of arrival and departure service sharing the common railway and operating facilities, the uitilization rates of station facilities consist of that of yard operation facilities and coal unloading plants. Eqs.(9) and (18) show the relationships about utilization rate of yard operation facilities and coal-unloading plants. From the viewpoints for making the utilization rate of station facilities to the maximun, the following objective functions can be established:

$$\text{Maximize } \rho_{13} \qquad (20)$$
$$\text{Maximize } \rho_{2} \qquad (21)$$

Owing to formulas as stated previously, the impacting factors to utilization rate of station facilities include numbers of working teams & facilities or coal-unloading plants which need to be decided, servicing rate and arrival density of train which are seen as external variables with stochastical feature.

Based on the study by T.CHISAKI *etal* (1994), under a certain transport demand of coal, arrival density of train can be calculated according to the distribution of the length of train, and each kind of servicing rate in the system will be derived from the distribution models of operating time. As decision variable, numbers of operating facilities can be installed through corresponding calculations.

2. Staying duration of train at station system

Staying duration of train at station system is an important part on measuring the rationality on the arrangement of station facilities, the utilization of those facilities and the determination of relevant scale. According to the present situation of railway system in China, staying duration of train at railway station occupies about 65% in total average trip circle time of freight wagon. So, it is very important to short staying time of train at station because it imply to be able to give full play to the rail transport capacity and to effectively utilize the facilities of station and freight wagons.

Staying duration of train at station system with sharing system of arrival and departure services includes two kinds of staying time at arrival-departure operation system and unloading operation system. From the viewpoint of shorting staying time to increase the efficiency of railway transport and rail facilities, the following objective function can be obtained.

$$\text{Minimize } Z = W_{s13} + W_{s2} = (W_{q13} + 1/\mu_{13}) + (W_{q2} + 1/\mu_{2}) \quad \text{(hours)} \qquad (22)$$

where Z: staying duration of train at station system.

According to the system characteristics, staying duration of train at the station will become longer with the increase of utilization rate of facilities. Based on these relations, utilization rate of operating facilities shall be controlled within a reasonable scope necessarily. compromise solution between two kinds of objective functions shall be pursued.

3.2 Constraint Conditions

To suffice these objectives, corresponding constraint conditions have to be considered.

1. Conditions of operating facilities: Numbers of facilities at each operation subsystem are needed more than one at least. In the station with sharing system of arrival & departure services, the facilities of each operation subsystem is need to meet the demands as follows:

$$C_{13} \geqq 1 \text{ and } C_{2} \geqq 1$$

2. Condition of station yard scale: The main roles of station yard based on coal port system are to supply corresponding place for arrival and departure operating and waiting trains and relative waiting trains for unloading operation. From the respect of land and ecomomic conditions, the yard scale is restrained within a certain scope as follows:

$$L_{ad} \leqq L_{ad}^{*}$$

where L_{ad}^{*}: allowable maximun scale of station yard (tracks).

3. Waiting time of train at each operation subsystem: Although the shorter waiting time of train at subsystem is expected, it is necessary to restrain waiting time within a reasonable scope from the whole viewpoint of station system. So, the following constraints can be led.

$$W_{q13} \leqq t_{13}^{*} \text{ and } W_{q2} \leqq t_{2}^{*}$$

where t_{13}^{*}, t_{2}^{*}: maximun values of waiting time which are permitted correspondingly to arrival-departure and unloading operation subsystems (hours).

4. Utilization rate of operating facilities: As to one of the objective functions of this programming, the utilization rate of operating facilities at relevant subsystem has to meet the following conditions.

$$0 < \rho_{13} < 1 \text{ and } 0 < \rho_{2} < 1$$

4. MATHEMATICAL ALGORITHM OF MODEL WITH FUZZY MEMBERSHIP FUNCTION

Based on those formulas as described previously, the corresponding mutiple-purpose optimum model about coal port station are found as follows;

$$\left.\begin{array}{l}\text{Maximize } \rho_{13} \\ \text{Maximize } \rho_{2} \\ \text{Minimize } Z=(W_{q13}+1/\mu_{13})+(W_{q2}+1/\mu_{2}) \\ \text{subject to} \\ \quad C_{13}\geqq 1 \text{ and } C_{2}\geqq 1, \\ \quad L_{ad}=L_{13}+L_{q2}\leqq L_{ad}^{*}, \\ \quad W_{q13}\leqq t_{13}^{*}, \\ \quad W_{q2}\leqq t_{2}^{*}, \\ \quad V=V_{0} \\ \quad 0<\rho_{13}<1 \text{ and } 0<\rho_{2}<1. \end{array}\right\} \tag{23}$$

where W_{q13} is given by one of Eqs.(1)~(6), W_{q2} by one of Eqs.(10)~(15), ρ_{13} and ρ_2 by Eqs.(9) and (18) respectively, V is the yearly coal transport demand (ton).

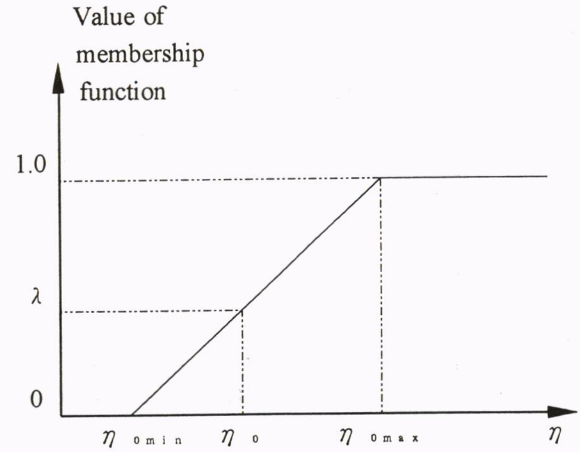

Fig. 3 Linear Membership Function of Objectives

As a multiple-purpose programming problem, virtually, it is very difficult that all of those objective functions are satisfied completely in the same time. Under certain facilities of station, from the respect of facility use, relevant utilization rate shall be increased as possible. But correspondingly, the waiting possibility of train will get greater. According to system characteristics, waiting time of train will change exponentially when utilization rate is over a certain value. Simultaneously, relevant yard scale of station needs to be enlarged. Therefore, we have to use fuzzy membership function in order to investigate some compromise among those objectives. Based on fuzzy theory, the membership function ($m(\eta_o)$) of objective function is defined as follows:

$$\left.\begin{array}{ll} m(\eta_o)=1.0 & (\eta_{omax}<\eta_o) \\ 0<m(\eta_o)<1.0 & (\eta_{omin}<\eta_o<\eta_{omax}) \\ m(\eta_o)=0 & (\eta_{omin}>\eta_o) \end{array}\right\} \tag{24}$$

And if $m(\eta_o)$ is assumed as a kind of linear function as shown in Fig. 3, the objective function for minimizing Z_o can be described in the following:

$$1-(\eta_o-\eta_{0min})/(\eta_{0max}-\eta_{0min})\geqq\lambda$$

The value of λ shall be made as great as possible, approaching η_o to η_{omin}.

The objective function for maximizing η_0 can be changed into:

$$(\eta_0 - \eta_{0min}) / (\eta_{0max} - \eta_{0min}) \geqq \lambda$$

The value of λ shall be made as great as possible, reaching η_0 to η_{0max}.

Considering all of those formulas as mentioned above, relevant mathemtatical model for the optimization of station system can be obtained as follows:

$$\left.\begin{array}{l} \text{Maximize } \lambda_0 = \text{Min.}(\lambda_1, \lambda_2, \lambda_3) \\ \text{subject to} \\ \quad (\rho_{13} - \rho_{13min}) / (\rho_{13max} - \rho_{13min}) \geqq \lambda_1 \\ \quad (\rho_2 - \rho_{2min}) / (\rho_{2max} - \rho_{2min}) \geqq \lambda_2 \\ \quad 1 - (Z - Z_{min}) / (Z_{max} - Z_{min}) \geqq \lambda_3 \\ \quad C_{13} \geqq 1 \text{ and } C_2 \geqq 1, \\ \quad L_{ad} = L_{13} + L_{q2} \leqq L_{ad}^*, \\ \quad W_{q13} \leqq t_{13}^* \text{ and } W_{q2} \leqq t_2^*, \\ \quad V = V_0, \\ \quad 0 < \rho_{13} < 1 \text{ and } 0 < \rho_2 < 1. \end{array}\right\} \quad (25)$$

and all of decision variables (λ_i, C_i) should be non-negative

As to the fields of nonlinear programming problem, although there are some computing methods concerning actual research subjects, no the sufficient methodology for general purpose is able to be established because of relevant complexity in the present situation. And the optimization model of station system is not only nonlinear programming problem, but also includes some stochastic elements which are unable to be judged simply with a certain formulations such as length of coal train, service time of train at each operation system. Therefore, owing to stochastic characteristics of relative elements, the resolutions of optimization problem for the station system will include some probability. In the computing procedure of the model, the solution based on different transport demands will be discussed in order to determine operating facilities and corresponding yard scales. Simultaneously, average value and standard derivation of ρ_i and staying duration of train as important index of station are investigated. According to these analyses, the simulation technical skill has to be used in the computing algorithm.

5. APPLICABLE ALTERNATIVES FOR THE IMPROVEMENT AND DETERMINATION OF STATION FACILITIES

As an application of optimization model, some situations to establish relevant station facilities based on different transport demands are stochastically discussed in the following.

The determination of station facilities should be combined with corresponding transport volume. Supposing that the transport demands are V=30, 40, 50, 60, 70 Mil.ton/year, seperately, the necessary scale of station yard, numbers of arrival-departure operating facilities and coal-unloading plants can correspondingly be decided. Simultaneously, some important indices including duration of train staying at station and utilization rate of relevant operating facilities are also respectively obtained.

Based on the calculating results of station system using the model as mentioned-above, Arrival-departure operation facilities according to different transport demands can be determined as shown in Fig. 4.

(1). C_{13}=2, the probability (Pr.) to meet the demand of V=30 Mil. ton/year is only 34%.

(2). C_{13}=3, the probabilities to meet the demands of V=30, 40 Mil.ton/year are 100% and 95%, respectively.

(3). C_{13}=4, the probabilities to meet the demands of V=50, 60, 70 Mil.ton/year are 99%, 93%, 68%, seperately.

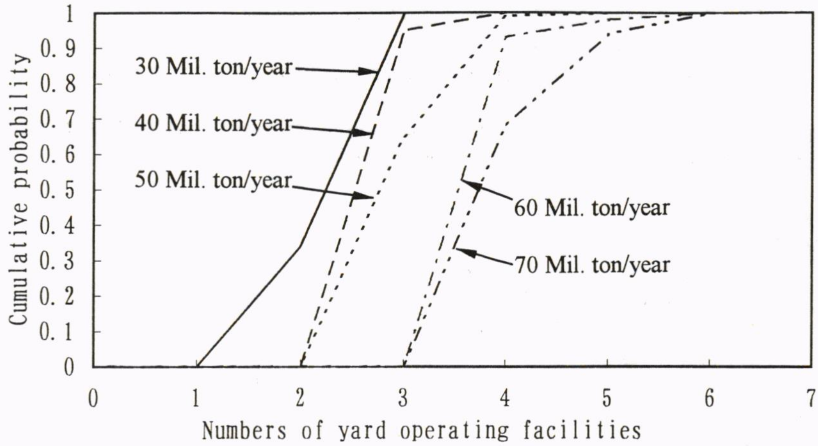

Fig. 4 Determination of arrival-departure operation facilities (C_{13}) based on coal transport demand

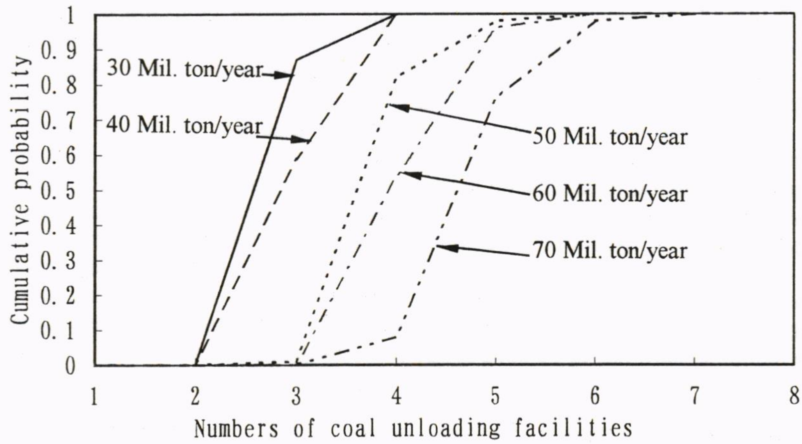

Fig. 5 Determination of unloading facilities (C_2) based on coal transport demand

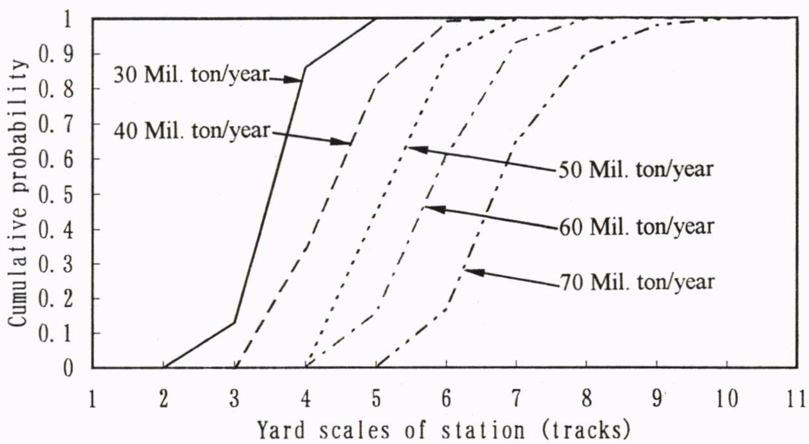

Fig. 6 Determination of yard scale of station (L_{ad}) based on coal transport demand

Similarly, Fig. 5 shows the determination of coal-unloading tipping plants (C_2) and corresponding probabilities to meet different transport demands.

As to the yard scale of station matching with a definite transport volume, From Fig. 6, it is can known as follows:

(1). L_{ad}=4 tracks for V=30 Mil. ton/year (Pr.=100%).

(2). L_{ad}=7 tracks for V=40, 50 Mil. ton/year (Pr.=100%) and V=60 Mil. ton/year (Pr.=93%).

(3). L_{ad}=9 tracks for V=70 Mil. ton/year (Pr.=98%).

In the meantime, once numbers of operating facilities (C_{13} and C_2) are decided, relevant utilization rates of these operating facilities and staying duration of coal train at station as important indices to evaluate and design the station system are also obtained as in Table 1. For example, in order to meet the demand of V=40 Mil.ton/year, if C_{13}=3 and C_2=4 are established, average utilization rate of C_{13} is 0.686, its corresponding deviation is 0.042, and that of C_2 are 0.752 and 0.073 , respectively. In the situation, the average duration of train staying at station is 3.768 (hour), its deviation is 0.444 (hour). And also, relevant indices for the station can be derived according to different coal transport volume.

Table 1 Some Important Indices of Station Corresponding with Transport Demand

Transport Demand	Utilization Rate of C_{13}			Utilization Rate of C_2			Duration of Train At Station (hour)	
(Mil. ton/year)	C_{13}	mean	deviation	C_2	mean	deviation	mean	deviation
30	3	0.632	0.098	3	0.661	0.051	3.704	0.547
40	3	0.686	0.042	4	0.752	0.073	3.768	0.444
50	4	0.747	0.067	5	0.743	0.051	3.749	0.399
60	5	0.719	0.039	5	0.779	0.058	3.571	0.396
70	5	0.768	0.058	6	0.777	0.052	3.669	0.440

6. CONCLUSIONS

The determination of station facilities, especially under multi-stage operation procedure, not only consider the utilization effectiveness of each facility, but also is a coordination problem among station elements.

This paper mainly discusses how to determine yard scale and operating facilities of railway station based on coal port system, using the queuing characteristics of each operation subsystem. The station system is a multi-stage operation procedure with intermodalization of coal railway transport and unloading on the basis of arrival-departure services sharing the common railway facilities and working teams. Because there are some stochastical elements and multiple-purpose problem in the system, a nonlinear programming model with multiple-purpose is constructed, and a systematical approach for solving the model adopting fuzzy membership is led. And with the help of simulation, some situations to determine the yard tracks, numbers of yard operating facilities and unloading tipping plants according to different transport volume are discussed with the probabilities to suffice the coal transport needs.

Simultaneously, when numbers of each operating facilities and yard tracks are decided under certain transport volume, as important indices for the design and evaluation of railway station, the relevant utilization rate of each operating facility and staying duration of train at coal port station are investigated, and their means and standard deviations are found out. These information will assist designers and planners in making-decision. And also, a kind of coordination relationships is realized by the assignment of station facilities matching with each other among operation subsystems at the station.

REFERENCES

Cao, R.Y. (1986) **Design of Harbour Rail Station and Its Arrangement of Facilities** (In Chinese), Northern Jiaotong University, Beijing.

Dong, Z. C. (1985) **Queuing Theory and Application** (In Chinese), published by Systems Engineering Society, Beijing.

Feng, H., He, X. R. (1987) **Design of Railway Station** (In Chinese), Railway Science Press, Beijing.

Shyu, G. H. (1988) **Stochastic Service System** (In Chinese), Science Press, Beijing.

Thomas, H. N., Joseph, L. B., Donald, S. B., Kong, C. (1966) **Computer Simulation Techniques**, John Wiley & Sons Inc., New York.

Abdou, G. and Dutta, S. P. (1993) A systematic simulation approach for the design of JIT manufactuering systems, **Journal of Operation Management**, 11 (3), 225-238.

Bastani, A. S. (1988) Analytical solution of closed-loop conveyor systems with discrete and deterministic material flow, **European Journal of Operation Research**, 35, 187-192.

Baunach, G. R., Wibberley, E. S. and Wood, B. R.(1985) Simulation of coal trasshipment terminal: Batam Island Indonesia, **Journal of Mathematics and Computer Simulation**, 27,115-120.

Chishaki Takeshi, Li Guoquan, Dong Zhongying and Huang Wen-Chih (1994) Distribution model of coal train arrival and each operation at coal port station (In Japanese), **Technology Reports of Kyushu University**, Vo67., No. 3 , 177-183.

Chishaki Takeshi, Li Guoquan and Huang Wen-Chih (1995) Queuing system and its characteristics of coal port station with sharing system of arrival and departure services (In Japanese), **Technology Reports of Kyushu University**, Vo68., No. 3 , 171-178.

Petersen E. R. (1977) Railway Modeling: Part I . Prediction of put-through time, **Transportation Science**, Vol., 11, No.1 37-49.

Petersen E. R. (1977) Railway Modeling: Part II . The effect of yard facilities on congestion, **Transportation Science**, Vol., 11, No.1 50-60.

Suleyman Ozekici (1987) Average waiting time in queues with scheduled batch services, **Transportation Science**, Vol., 21,No. 1, 55-60.