Evaluation Method for Appropriate Fleet Size of Forklifts at a Freight Station

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***Abstract*— In a freight station in Japan, the number of forklifts is determined experientially based on the quantity of work, shape of a container platform and operating time. But, it is difficult to evaluate the appropriateness of the number of forklifts quantitatively. So, the author developed a simulator of cargo handling operations in freight stations, and studied influences of the fleet size on the works of loading and unloading. As a result, it was found that the waiting time of trucks for loading or unloading was correlated with operation rate of forklifts. The shortening of the waiting time of trucks is desirable from the point of view of customer satisfaction. In this paper, the author proposes a method to evaluate the appropriateness of the size of the forklift based on operation rate of forklifts.**

Keywords- Fleet size of Folklifts; Freight Station; Cargo handling operation

I. Introduction

Rail freight transportation in Japan is mostly operated by Japan Freight Railway Company (JR Freight). Most of the lines that JR Freight uses are owned by passenger railway companies, and JR Freight operates their trains by making them wedged in between the operation of passenger's trains. Japanese passenger railway is well known for its high density and punctuality, so that freight trains also must be punctual for arriving or departing time.

Over 700 freight trains are operated on the average each day in Japan. Of these, about 400 trains are container trains [1]. The freight stations used to handle container trains have "container platforms" surrounding the tracks for loading and unloading containers, and containers are loaded onto trains from container platforms or unloaded from trains onto container platforms by forklifts(Fig. 1). Transportation companies that are commissioned to take care of the containers go to container platform and load or unload containers onto/from own truck there using forklifts.

As large-scale freight station must handle over 50 trains (sum of arrival and departure trains) per a day, schedule of freight cars and locomotives in such large-scale freight stations must be planned in detail. In addition, most transportation companies bring out their containers in a few hours from arrival of freight trains, and some companies bring in their containers just before a deadline. Therefore, handling operation becomes very complicated and difficult.

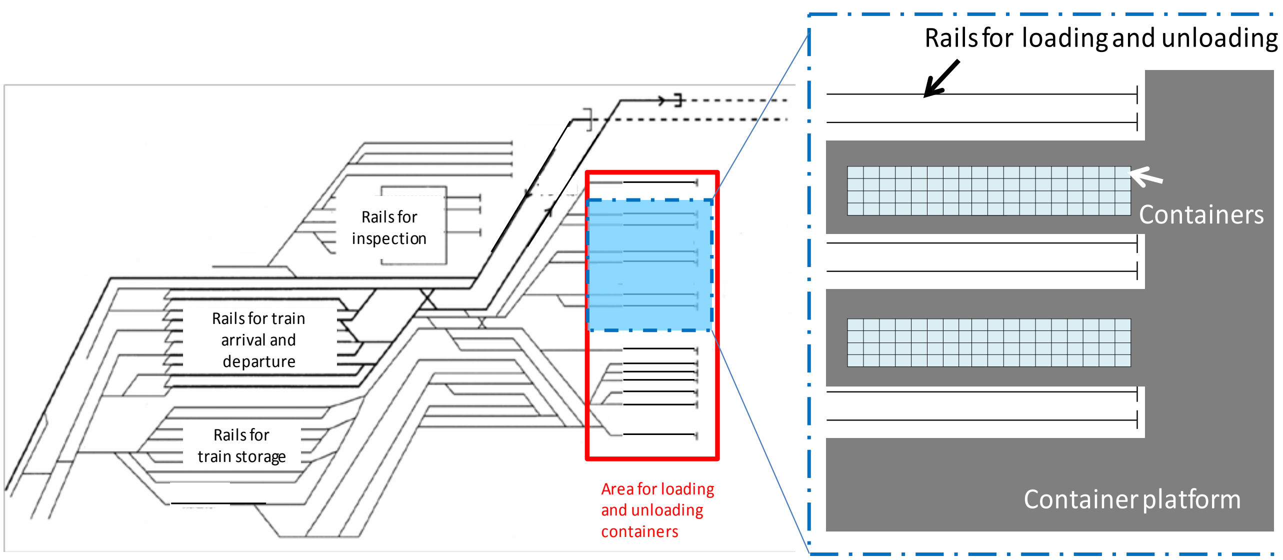

Figure 1. Example of Japanese Freight Station

Figure 2. Classification of cargo handling operations

TABLE 1. PRIMARY OPERATIONS

Brought in by	Brought out by	Container handling
Storage	Storage	*No handling*
	Train	Storage → Yard truck → Container platform → Freight car
		Storage → Freight car
	Forwarder	Storage → Forwarder's truck
Train	Storage	Freight car → Container platform
	Train	Freight car → Yard truck → Container platform → Freight car
		Freight car → Container platform → Freight car
	Forwarder	Freight car → Container platform → Forwarder's truck
Forwarder	Storage	Forwarder's truck → Container platform
	Train	Forwarder's truck → Container platform → Freight car

At Japanese freight stations, forklifts and other cargo handling equipment are used to load and unload containers. Up until now, decisions on how many forklifts should be assigned to a freight station have been based on experience , based on a number of cargo works, a shape of the yard, working hours, and so on. It is difficult to determine whether the current number of forklifts assigned is too large, too small or appropriate. Quantitative analysis for appropriate assignment of resources has been a challenge. Against such background, the author developed a simulator program that is capable of analyzing the impact of the number of forklifts assigned to a freight station against the loading operations at the station. This paper introduces how the simulator program is used to assess the adequacy of the number of assigned forklifts.

JR Freight has introduced the system "IT-FRENS SYSTEM (IT FREight information Network System)" that integrates management of containers in 2004 [2]. By using this system, we can grasp move of containers and move of forklifts in a freight station. The author developed the cargo handling simulator based on analysis of these data.

The behavior of forklifts has been studied in the domain of warehouse. These researches aim at creating efficiency of picking or optimizing layout of a warehouse [3][4][5]. Therefore, it is difficult to apply the results of these researches to Japanese freight stations. The loading in ship transportation has been studied for many years [6][7][8], but it is difficult to apply these study results to the railway sector because the feature of loading and unloading facilities, and the method of loading and unloading in ship transportation are different from these in railway transportation.

II. CLASSIFICATION OF CARGO HANDLING OPERATIONS AT FREIGHT STATIONS

The author classified the cargo handling operations at freight stations using the operation histories of forklifts used

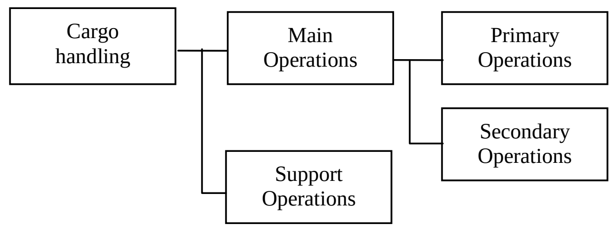

Figure 2. Classification of cargo handling operations

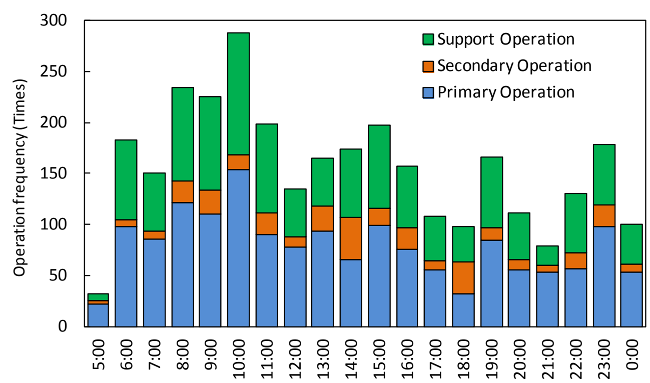

Figure 3. Frequencies of Support, Primary and Secondary Operations

at the stations. As shown in Fig. 2, cargo handling operations are classified into Main Operations (moving the container) and Support Operations (moving away containers above or in front of a container to gain access to the container). Furthermore, Main Operations are subdivided into Primary Operations (operations typically carried out from when the container is brought into the station up to when the container is brought out, which are outlined in Table 1) and Secondary Operations (rearranging the station premises and cargo stacks to facilitate the handling of the container). Frequencies of Support, Primary and Secondary Operations at a freight station are shown in Fig. 3. It indicates that Support Operations account for roughly 40%

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of all operations and that there are only small variations in the ratio between Support and Primary Operations throughout the day.

III. Limitations on Cargo Handling

Typical limitations on cargo handling are described below.

A. *Time-related limitations*

- The time specified in the yard operation plans (i.e., time for trains pulling into and out of the container platform) must be observed.
- Waiting time of the forwarders' trucks should be minimized to achieve customer satisfaction.
- Appropriate sequence of cargo handling shall be taken into consideration, such as the flow of Primary Operations shown in Table 1, loading and unloading operations performed in the same area, etc.

B. *Limitations posed by variations of containers*

- Some sizes of cargo handling machines must be used in accordance with the size of container to be handled.
- At most freight stations, storage areas of the containers are specified according to their sizes

C. *Spatial limitations*

- Support Operations need to be considered according to the current container storage status.
- If the specified container storage space is fully occupied, excess containers shall be stored in nearby vacant space.
- The container platform has only a limited space for moving and some areas have restrictions such as one-way traffic.
- The cargo handling operations should be arranged so that the total distance travelled by forklifts is kept as short as possible.

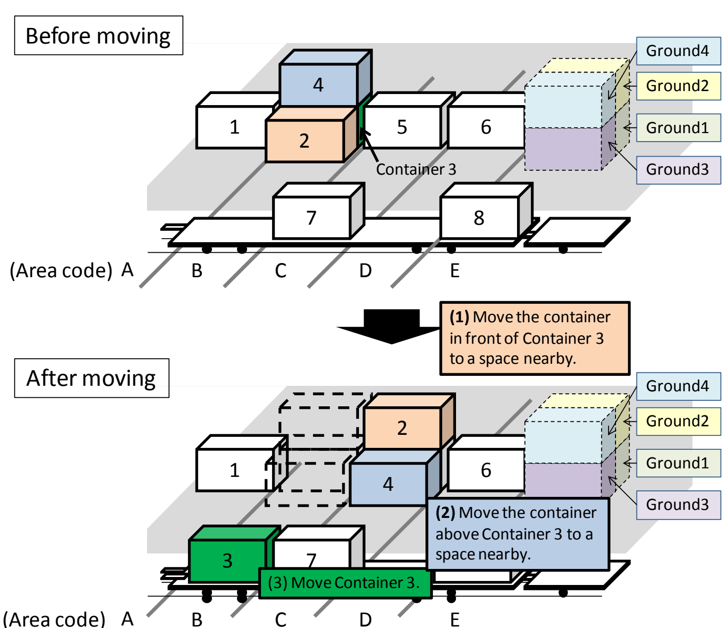
To estimate the appropriate number of forklifts that should be assigned to a freight station to properly perform cargo handling operations under the limitations described above, a clear picture of the operations of the forklifts in a given environment including the layout of the station, the status of the containers and temporal distribution of the cargo handling work needs to be formed. For this purpose, the author developed a simulator program.

IV. Development of Cargo Handling Simulator Program

A. *Modeling of freight station*

Container platforms are normally complex in shape as they are constructed around cargo handling tracks, which makes simulation difficult. Moreover, as the locations of container yards and the areas where forklifts can travel are restricted, the distance a forklift actually travels is not the direct distance between any two points. To overcome this, the container storage areas at a freight station were created in a multidimensional space by defining the time taken to travel between two storage areas as a corresponding distance in a Euclidean space.

For each area, arrays for the number of containers that can be stored on that container platform, trucks and freight cars (if the area is served by adjoining tracks) were assigned.



	Area A	Area B	Area C	Area D	Area E
Ground1	Container 1	Container 3	Container 5	Container 6	
Ground2		Container 4			
Ground3		Container 2			
Ground4					
Truck					
Freight car			Container 7		Container 8

	Area A	Area B	Area C	Area D	Area E
Ground1	Container 1		Container 5	Container 6	
Ground2			Container 2		
Ground3			Container 4		
Ground4					
Truck					
Freight car		Container 3	Container 7		Container 8

*Grounds 1 to 4 are arranged according to the container stack.

Figure 4. Modeling of storage area

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The storage conditions of that area were explained by storing the container IDs in the arrays. The algorithm was designed in such a way that containers that were behind or beneath other containers could not be moved, and so that container IDs could not be stored in the train or truck array unless trains or trucks were available. For the latter, operation management data of trucks and trains is utilized.

The modeling enables changes of container locations made by forklifts to be represented by changes of the relevant container IDs stored in the arrays. For example, as shown in Fig. 4, moving Container 3 to Area B of a freight car requires a Support Operation consisting of moving away Container 2 from in front of Container 3 as well as Container 4 from above Container 3. These location changes are represented by the relevant changes in the tables in Fig. 4.

B. *Simulation algorithm*

The developed simulator program employs a time-driven algorithm for assignment of cargo handling jobs. The algorithm is shown in Fig. 5. The simulation utilizes not just the arrays of containers stored on the station premises but a database on the status of available forklifts and another database on the status of Main Operations. Changes on the station premises are produced by changing these data with a lapse of time. The Main Operation database is created based on input data. Each Main Operation job is given a ready-to-start time. The arrival of a train or truck can be simulated by assigning the ready-to-start time to the time when the train or truck has arrived and cargo handling operation has become possible. Each record in the Main Operation database is time-sequence enabled to ensure a job (e.g., loading a container to a truck) cannot be started until the previous job (e.g., unloading an existing container from the truck) is completed. This can also be applied to Primary Operations in Table 1.

Job assignment to available forklifts is determined based on a prioritized order of ready-to-start jobs, which is calculated based on job types, deadlines, wait time and other parameters, and the work areas of forklifts, which is calculated based on the distribution of cargo handling jobs and forklifts and the operation status of forklifts. The method of determine the priority order depends on custom and circumstance of each station so that we must prepare an expression corresponding to each station.

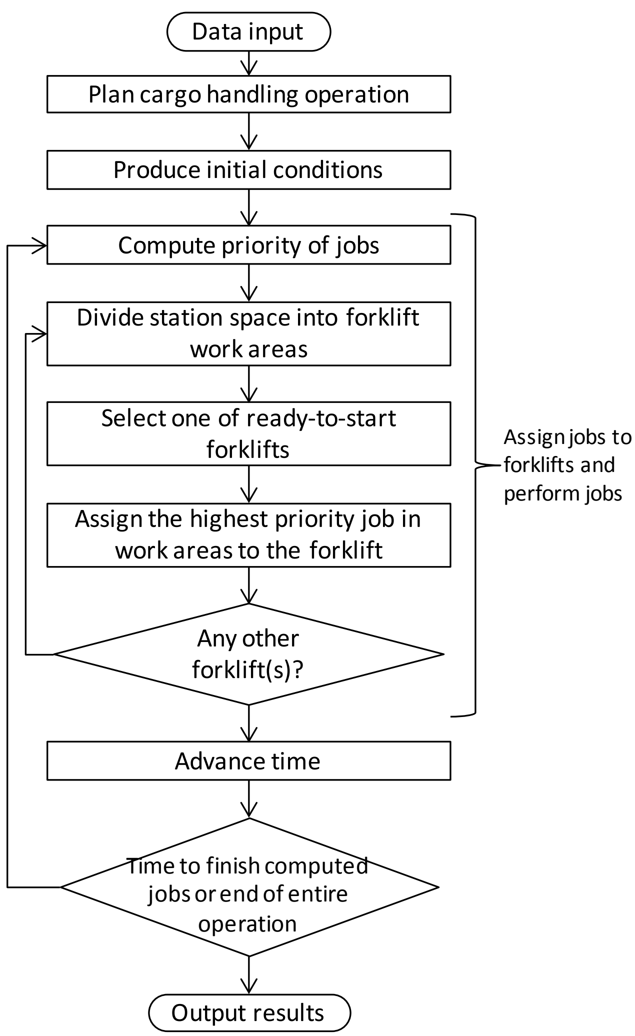

Figure 5. Simulation's computational flow

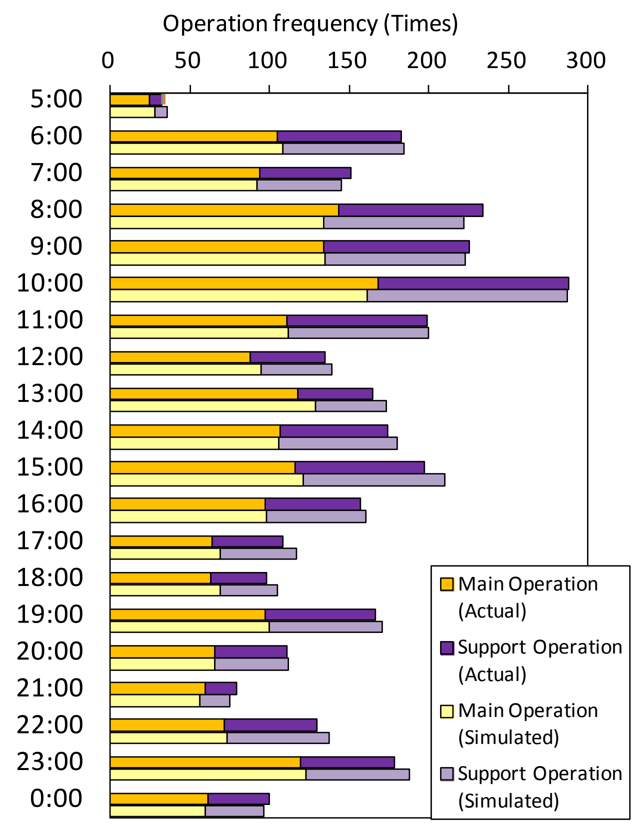

Figure 6. Comparison of actual and simulated operation frequencies

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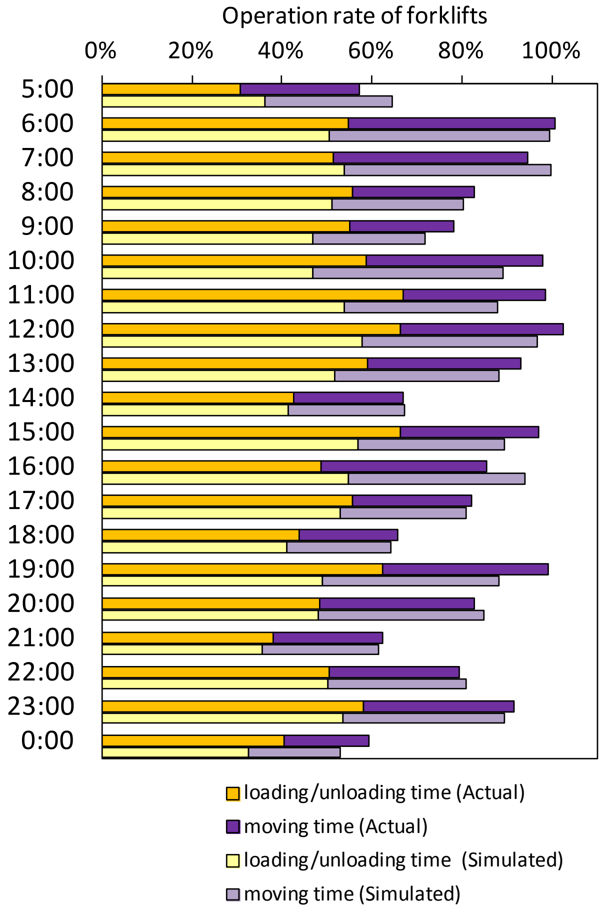

Figure 7. Comparison of the ratio of moving time and loading/unloading time

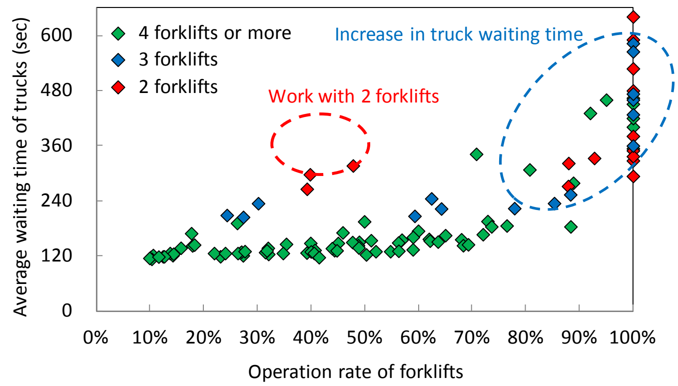

Figure 8. Relationship between the operating rate of forklifts and the average waiting time of trucks

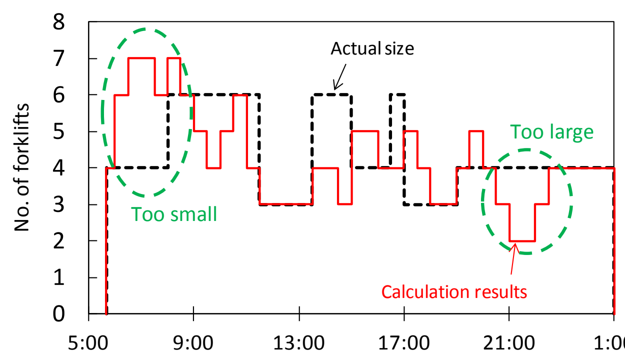

Figure 9. Calculation of efficient fleet size

C. Verification of cargo handling simulator program

The simulation program was verified using the actual data of a freight station. Data covering one day at the station was imported and a simulation was conducted for comparison between the actual data and the simulation result. Fig. 6 shows the frequencies of Main and Support Operations for each time zone. Fig. 7 shows the ratio of time spent moving containers out of the forklift operation time for both Main and Support Operations. Both figures indicate a good reproduction of the actual data. With the results, the simulator can be considered accurate enough for practical application to forklift fleet size evaluation.

V. Fleet Size Evaluation Methods Using Cargo Handling Simulator Program

The simulator program offers the facility to increase and decrease a forklift fleet size and observe the results. Through a trial an d error process with the simulator, it is possible to determine the size of a forklift fleet that offers efficient operation with minimum idle time. The result can then be used to evaluate the current fleet size. However, performing such evaluation while changing the fleet size with hours can involve too many combinations to consider. Instead, simulation was performed to find out how average waiting time of forwarders' trucks could be minimized.

For this simulation, using actual facility data of a freight station, cargo handling jobs were randomly generated while the size of a forklift fleet was changed. The relationship between the operation rate of forklifts and the average waiting time of forwarders' trucks is shown in Fig. 8.

With a fleet of two forklifts, the average waiting time can be relatively long even when the operating rate of the forklifts is low, indicating the fleet is too small for the size of the station (i.e., too much time spent traveling between containers on the premises). With a fleet of three forklifts or more, the average waiting time starts to increase suddenly when the operating rate becomes around 80 to 90%. In other words, keeping the operating rate below 80% can be effective in preventing the waiting time from becoming too long.

Keeping the 80% threshold in mind, it is possible to identify the time when the fleet size is too small or too large by calculating the fleet size that can keep the operating rate below 80% based on actual workload data and then comparing the result with the actual fleet size. (Fig. 9 shows the result of calculation, in which the fleet size was changeable every 30 minutes.) By observing the actual data for several days to check if chronic fleet excess or shortage occurs at any time of the day, the appropriateness of the fleet size can be evaluated.

VI. CONCLUSION

The author developed a simulator program to simulate the cargo handling operations at a freight station and proposed a method to evaluate the appropriateness of the size of the forklift fleet using this program. In determining the actual fleet size for an existing freight station, however, a range of parameters still need to be considered including operators' work schedules and variations in cargo handling workload.

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