Research Article

Efficiency Improvement of Truck Queuing System in the Freight Unloading Process Case Study of a Private Port in Songkhla Province

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Abstract

This study aimed to improve the efficiency of queuing system of supply trucks in freight unloading process in a private port in Songkhla province. In everyday, suppliers delivered 5 types of supply to the port, including (1) oil-rig spare parts, (2) consumer products, (3) tools and chemicals, (4) helicopter fuel, and (5) plastic bins. Each truck consumed unequal operation time. The operation process was improved by method analysis and ECRS technique. Then, several models of truck scheduling were compared using Monte Carlo simulation technique. The models composed of first-come, first-served (FCFS), shortest process time (SPT), longest processing time (LPT), and analytic hierarchy process (AHP) of both original (O) and new improved (N) processes. The result showed that New Longest Processing Time (NLPT) was the most efficient model, which reduced 77.2% in mean waiting time, decreased 69.0% in mean total time in system, and improved from 11.94% to 35.30% in system utilization.

Key Words: Efficiency; Freight unloading; Monte Carlo simulation; Truck queuing

Introduction

The problem of truck queuing system occurred frequently in many private ports in Thailand. Due to the fact that the private sector was authorized a limited quota in port space by the government whilst an increasing demand in logistics service grew rapidly, an insufficient resource caused the congestion in supply transportation process.

The case study was a company related to oil and natural gas business, which need to deliver the daily supplies from land to oil platform through their port in Songkhla province. The port had a limited working area and a deficient parking lot, which had a space for just 10 trucks. Furthermore, a single crane was utilized for transferring the containers and bundles of various supplies from each incoming truck to the supply boat, which served as first-come, first-served (FCFS). The operation time of each jobs depended on the type of supply. There were 5 types of supply, including (1) oil-rig spare parts (RP), (2) consumer products (CP), (3) tools and chemicals (TC), (4) helicopter fuel (HF), and (5) plastic bins (PB). These limitations caused a long queue of waiting trucks to make a noise and pollution from their emission. Subsequently, this port was prosecuted by the neighboring communities about the environmental concern. The judgment resulted in a ban to close the port for 10 days and also compensated the penalty from the supplier around 50,000 baht per working hour.

From above reason, the approach of method analysis and scheduling was selected to solve this problem because method analysis used operation analysis to study all productive and non-productive elements of an operation, to increase productivity per unit or time, and to reduce unit costs while maintaining or improving quality (Niebel and Freivalds, 2003). Many previous studies focused on the queuing problem, including Lee et al (1997) studied about server unavailability to reduce mean waiting time in some service queuing system and Tian and Tong (2011) improved the queuing system of bank based on business process reengineering.

In addition, scheduling was an important aspect of operations control in both manufacturing and service industries, such as Thongsanit (2014) applied integer linear programming to solve classroom timetable assignment problem. With increased emphasis on time to market and time to volume as well as improved customer satisfaction, efficient scheduling gained increasing emphasis in the operations function. Various sequences were proposed. For example; Namias (2001) compared the FCFS (first-come, first-served), SPT (shortest processing time), EDD (earliest due date), and CR (critical ratio) for job shop scheduling, Koulamas and Kyparisis (2009) modified the LPT (longest processing time) for the two uniform machine makespan minimization problem, Woottichaiwat et al (2011) applied the AHP (analytic hierarchy process) to sort the priority of the freights on supply boat.

However, to find the most appropriate solution, the simulation was needed. Because this truck queuing problem was not the complex system, the commercial simulation software (i.e. Arena, ProModel) was unnecessary. So, the recent spreadsheet technology was effective enough for conducting Monte Carlo simulation of the simple dynamic system (Harrell et al., 2012). The Monte Carlo simulation estimated the expected waiting time and service times and developed an optimum solution through a proper balance of service stations, servicing rates, and arrival rate. This technique was most helpful for analyzing the waiting line problem involved in the centralized-decentralized storage location of tools, supplies, and service facilities (Niebel and Freivalds, 2003).

Therefore, the aim of this study was to improve the efficiency of the truck queuing system in freight unloading process through method analysis and truck scheduling. Many sequences of supply truck were also investigated, including FCFS, SPT, LPT and AHP of both original process (O) and new improved process (N). To compare the results among 8 sequences, a hundred of simulations were carried out using Monte Carlo technique on spreadsheet. The efficiency indicators consisted of (1) mean waiting time, (2) mean total time in system, and (3) system utilization.

Research Methodologies

Survey and data collection

The layout of the case study port and the operation processes of freight unloading were initially investigated and then summarized using flow diagram. Besides, the operating times of each job, the arrival times of the supply trucks, and its distributions, which were the data for simulation, were daily collected for one year.

Method analysis

To diagnose the inefficient and unproductive activities, the method of original operation was analyzed and the method of new operation improved using ECRS technique was subsequently proposed. The ECRS technique was one of work study approach for activity optimization and frequently employed to improve the productivity of operations or production processes, consisting of eliminating (E) the unnecessary or redundant activity, combining (C) the activity if elimination was not possible, rearrange (R) the sequence of jobs for better performance, and simplify (S) the method (Niebel and Freivalds, 2003).

Truck scheduling

In this study, the 4 sequences of truck schedule were chosen to compare the efficiency of both original and new operation processes. The selected sequences consisted of (1) FCFS was a sequence in which the jobs entered the server; (2) SPT was a sequence of an increasing order of the processing time, which the job with the shortest processing time was first, the job with the next shortest processing time was second, and so on; (3) LPT was opposite in sequence to SPT; and (4) AHP (analytic hierarchy process) was a sequence based on a priority of the jobs. Then, such algorithms were formulated into 8 simulation models, including Original First-Come First-Serve (OFCFS), Original Shortest Processing Time (OSPT), Original Longest Processing Time (OLPT), Original Analytic Hierarchy Process (OAHP), New First-Come First-Serve (NFCFS), New Shortest Processing Time (NSPT), New Longest Processing Time (NLPT) and New Analytic Hierarchy Process (NAHP).

Monte Carlo simulation

To compare the efficiency of each model, all models were simulated by Monte Carlo technique using spreadsheet program. The distributions of the arrival time of supply truck and the operating time of each activity were assumed as exponential and normal distributions, respectively.

To simulate the arrival of the trucks, a random number was generated to produce observations from exponential distribution. The inverse transformation method was used for this purpose. The transformation equation was

$$X_i = -\beta \ ln\ (1 - RN_i) \qquad (1)$$

where X_i represented the arrival time of the *i*th truck realized from the exponential distribution with mean time of β, and *RN* was the ith random number from RAND() function in MS Excel.

In addition, the data of operating time was simulated as normal distribution with an average and standard deviation from the observation. The transformation equation was

$$Y_i = NORM.INV(RN,Average,SD) \qquad (2)$$

where Y_i represented the operating time of the *i*th job as normal distribution using the inverse normal function in MS Excel with the average and standard deviation (SD), and *RN* was the *i*th random number as the probability of each job.

Afterwards, the simulation of each model was repeated until the average of the results converged toward the steady state. In other words, the replication was continued until the average values of the results were stable.

Results and Discussion

Process improvement

Figure 1 illustrates the flow diagram of the original operation of unloading process. The operation began with the arrival of supply trucks. The truck waited in the parking lot until the entrance gate opened. The first queue of truck started from the 2nd position to 4th position. Before the truck came into the port, the gate officer checked the entry permit of driver and truck at the 5th position. The truck then drove to the unloading station at the 8th position. After unloading completed, the QC officer at the 10th position checked the physical condition of the container and the supply before loading onto the boat, while the empty truck must waited until the checking finished. Afterwards, the truck drove to the 13th position to check an invoice before exiting the port.

As a result of the process improvement, the delay activities in 4th, 7th, 9th, and 12th position were eliminated by assigning the time table for each supply type. Additionally, the inspection processes in 10th and 13th position were combined and then simplified using a checking list form to reduce the operation time. Afterwards, the transport processes in 11th and 14th position were also merged. The results of this improvement was concluded in Figure 2 and Table 1.

Figure 2 shows the flow diagram of the improved operation of the process. The non-productive activities in the original operation were removed by using ECRS technique, including transport, delay and inspection activities.

Table 1 summarizes all activities of both original and improved operations categorized by ASME standard symbols. The number of total activities was reduced from 13 activities to 8 activities. For examples; the delays of the process were diminished from 5 locations to 1 location by eliminating the excess queuing locations and rearranging the time schedule of each supply truck. An appointment was employed to get rid of the waiting queue of the truck. Furthermore, the inspection activities were combined from 3 locations to 2 locations. These process

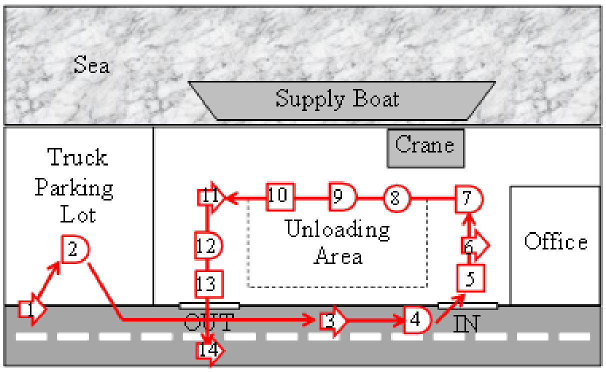

Figure 1 Flow diagram of the original operations of the freight unloading process

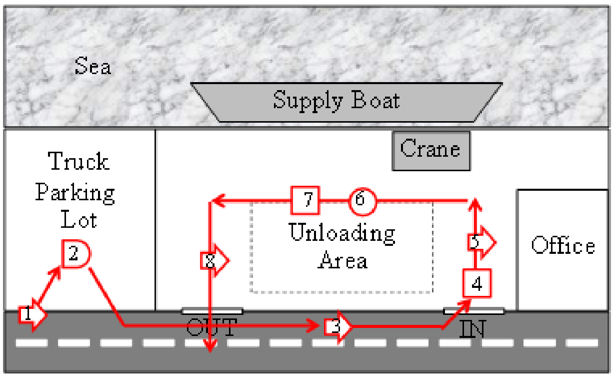

Figure 2 Flow diagram of the new improved operation of the freight unloading process

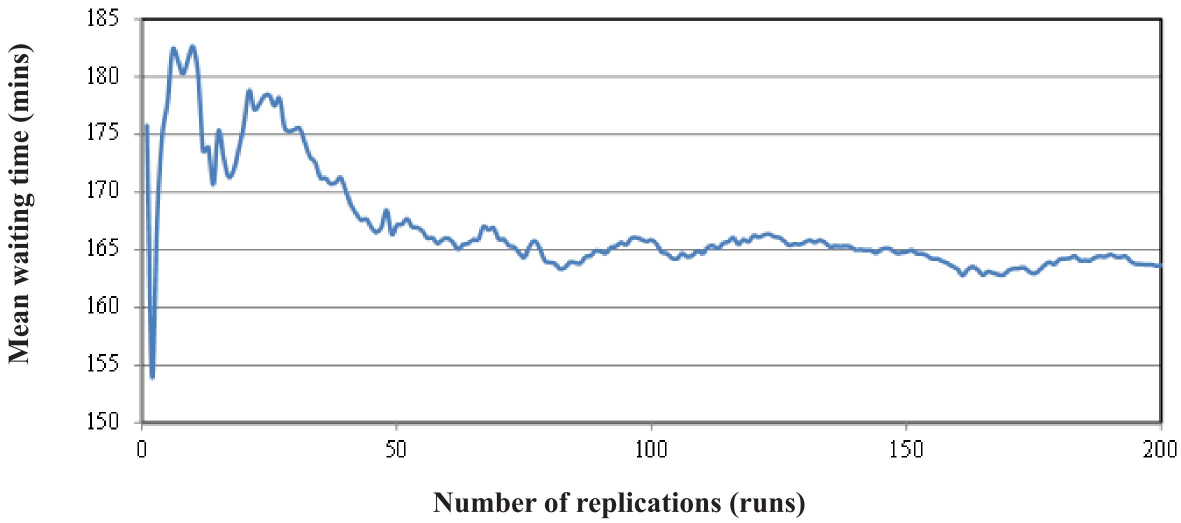

Figure 3 Relation between the number of replications and the mean waiting time of the OFCFS model

improvements obviously enhanced the efficiency of the queuing system.

Simulation models

The time data and distributions collected from time study were utilized for all 8 simulation models. Table 2 lists the operating time of each activity in unloading process. The unloading time for each supply type was different depending on its type. The unloading RP activity was the most time consuming operation. Because the oil-rig spare part was the most expensive, and vulnerable. Table 3 tabulates the probability distribution of supply types. It seemed the RP was the largest proportion of 0.53, while the HF was the smallest proportion of 0.03.

After modeling, the appropriate replication was determined in order to verify the results. Usually, the average of data fluctuated in the transient state and then converged in the steady state. Figure 3 plots the relation graph between the number of replications and the mean waiting time of the OFCFS model. From this figure, the mean waiting time began the transition to steady state at the replication of about 50 runs. So, finding an appropriate replication was conducted for 24 experiments.

Table 4 summarizes the number of replications at steady state of all 24 experiments. The mean total time in system from the OSPT model appeared to have the maximum replications of 140 runs. It seemed that

Table 1 Summary of activities categorized by ASME standard symbols

Activity		Number of Activities	
		Original Operation (O)	New Improved Operation (N)
Operation	○	1	1
Transport	⇨	5	4
Delay	D	5	1
Inspection	□	3	2
Storage	▽	-	-
Total		14	8

Table 2 Operating time of each activity in unloading process

Activity	Operating time (mins)	
	Average	SD
Checking the document.	3.49	1.89
Unloading		
RP: Oil-rig spare parts	12.56	4.22
CP: Consumer products	8.39	4.83
TC: Tools and chemicals	11.32	6.44
HF: Helicopter fuel	10.28	6.26
PB: Plastic bins	3.56	2.35
Inspection of container and supply	8.48	3.45

Table 3 Probability distribution of supply types

Type of Supply	Proportion
RP: Oil-rig spare parts	0.53
CP: Consumer products	0.31
TC: Tools and chemicals	0.08
HF: Helicopter fuel	0.03
PB: Plastic bins	0.05

Table 4 The number of replications at steady state

Model	Number of replications		
	Mean waiting time (runs)	Mean total time in system (runs)	System utilization (runs)
OFCFS	50	75	50
OSPT	90	140	100
OLPT	60	70	120
OAHP	70	40	120
NFCFS	50	20	110
NSPT	80	75	120
NLPT	90	100	120
NAHP	100	40	40

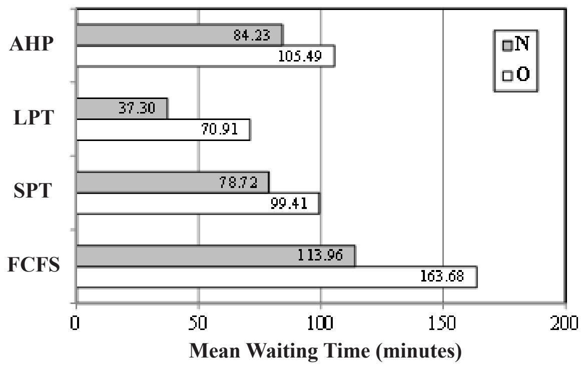

Figure 4 Comparison of the mean waiting times among various models

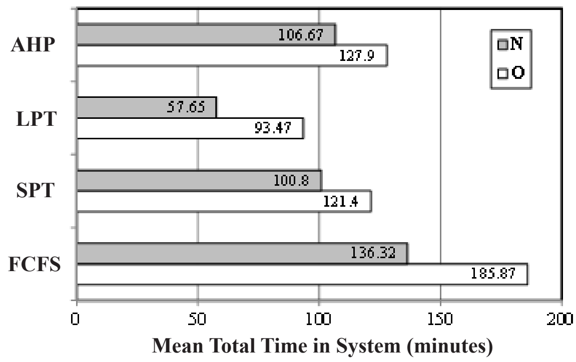

Figure 5 Comparison of the mean total times in system among various models

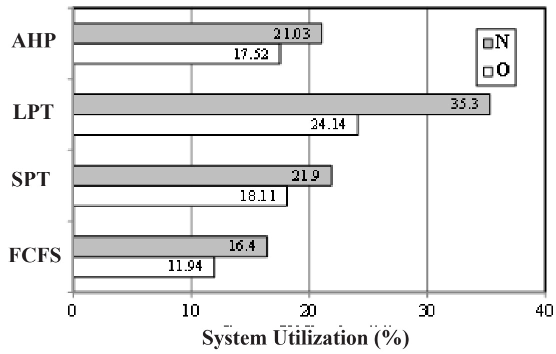

Figure 6 Comparison of system utilization among various models

the replication of over 140 runs could confirm all models to steady state. Consequently, the number of replications in this study was determined for 200 runs.

Efficiency of the queuing system

In this study, the simulation provided the results of mean waiting time, mean total time in system and system utilization. The OFCFS model represented the original operation of unloading process in the case study port.

Figure 4 exhibits the comparison of the mean waiting times among all models. It seemed that the process improvement in FCFS models could reduce the mean waiting time for approximately 50 minutes or improved the efficiency of around 30%. Additionally, NLPT showed a minimum in the mean waiting time, which was less than OFCFS about 126 minutes or 77.2%. The dramatic reduction was attributed to the appointment of truck schedule.

Figure 5 illustrates the comparison of the mean total times in system among all models. The results manifested in the same direction of the mean waiting time. The ECRS technique in process improvement decreased the total time of truck in the system. Moreover, NLPT remained to show a minimum in the mean total time, which dropped from 185.87 minutes to 57.65 minutes, or approximately 69%.

Figure 6 presents the comparison of the system utilization among all models. The OFCFS displayed the poorest efficiency in system utilization of 11.94%, whilst the NLPT performed the best efficiency of 35.30%. An improvement in the system utilization of 23.36% was caused by both of process improvement and truck scheduling.

From the above results, it seemed that NLPT was the best solution for this case study. The performances of all scheduling models sorting by descending were LPT, SPT, AHP, and FCFS, respectively.

Conclusion

The waiting time and total time in system could be reduced by process improvement using method analysis, resulting in an increase of system utilization. The ECRS technique seemed to be the effective tool for efficiency improvement. Moreover, truck scheduling was another way to improve the efficiency of the operation in the port. For this case study, it appeared that the longest processing time (LPT) model was the best model for the efficiency improvement.

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