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SIMULATION MODELS FOR CEMENT LOADING PROCESS

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Reduction of waiting and throughput times of cement trucks in cement-loading processes generally requires additional input resources, such as cement-loading machines and operators. However, a superfluous number of input resources can increase idle time. On the other hand, minimizing input server resources can significantly save costs for cement plants, but would result in excessive waiting time and throughput time of trucks, limiting the number of trips that trucks could travel to transport cement. To maximize the utilization of cement trucks and input resources, a trade-off between truck waiting time and server idle time is necessary. This study developed a simulation model maximizing the utilization factor of truck waiting time and machine idle time. By using EZStrobe software, the current operations of the cement-loading process were simulated based on data obtained between August 2012 and June 2013 at Asia Cement Plant, Thailand. The results show that a new design of operations with alternate layout, which operates by using four regular cement-loading channels with two extra channels during the 8-hour peak duration, is recommended for the cement-loading process to optimize performance, since they reduce truck waiting time, throughput time, and queue length, with the lowest machine idle time possible.

Keywords: Waiting time, Throughput time, Idle time, EZStrobe.

1 CEMENT LOADING PROCESS OVERVIEW

The process analysis of the batch cement-loading process at the Asia Cement Plant, Thailand, begins when a cement truck measures its weight at a weighbridge while queuing at the loading site that has a maximum capacity of 40 trucks. There are six weighbridges at this station: three weighbridges measure the weight of trucks entering the site, and three are used to check truck weight after loading cement.

The bulk cement-loading system consists of ten loading channels, with one cement-loading machine in each channel. Only one cement truck can be loaded at a time in a channel. The cement-loading channels are categorized into two lines based on a queuing system: line 1 and line 2 (Figure 1). Line 1 has four channels, nos. 23 to 26; line 2 has six channels, nos. 27- 28, and nos. 30-32. When a channel is available, the truck proceeds to the cement-loading channel, which draws cement from its silo. When the truck is fully loaded with 30 tons of cement, it is sealed and travels to the weighbridge to double-check their weight.

The current practice yields an average waiting time of 26 minutes per truck and throughput time of 71.5 minutes per truck, yielding 47.5 minutes of non-productive time per truck, compared to 24 minutes of cement-loading time.

2 TRUCK ARRIVAL CHARACTERISTICS

Raw data with a population size of 36,689 trucks was used to analyze and calculate parameters for the cement-loading process model. Average truck arrival rates during each 1-hour period were plotted to see the arrival characteristics of trucks at the cement plant. Obviously the truck arrival rate is not steady over time since a peak curve is found, as illustrated in Figure 2.

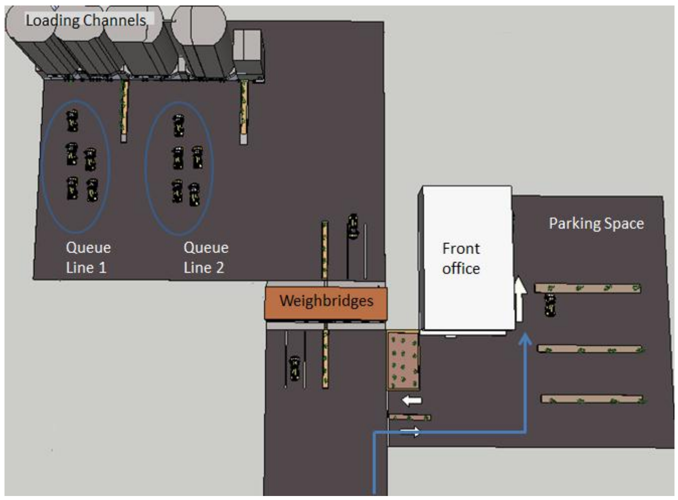

Figure 1. Layout of the site where the cement-loading process takes place.

As a result, truck arrival rates were classified into four phases in order to simulate the behavior of truck arrival characteristics during the day. The 5-hour peak period runs from 2.00 pm to 6.59 pm, while the 5-hour off-peak period runs from 10.00 pm to 02.59 am. The am and pm mid-peak periods have durations of 11 hours and 3 hours, respectively. Parameters of each period are shown in Table 1.

3 SIMULATION MODELS

3.1 Model of the Existing Process

The current practice of the bulk cement-loading process was simulated on EZStrobe (Martinez 2001) by using parameters based on statistical distributions. A model validation was conducted to measure how accurately the cement-loading process can be predicted by the simulation model. The simulation model is shown to predict truck waiting time, loading time, throughput time, and other related parameters with reasonable accuracy. There were no parameters with more than 6% error when the data obtained from the prototype model and actual data were compared.

3.2 Improvement Models

Improvement models were developed based on two flaws observed from simulation of the existing cement-loading process. First, an imbalance occurs in the queuing system. That is to say, the average number of trucks queuing in line 2 is greater than the average number of trucks waiting in line 1. The study opted to merge the two queue lines, rather than performing line balancing. Secondly, the number of trucks present in the system is high during the peak and mid-peak periods. Consequently, additional loading channels should be added to the model during these periods, for the sake of reducing the queue length by increasing the capacity of the system. However, every model created in this study shares the truck generator and process components, as shown in Figure 3.

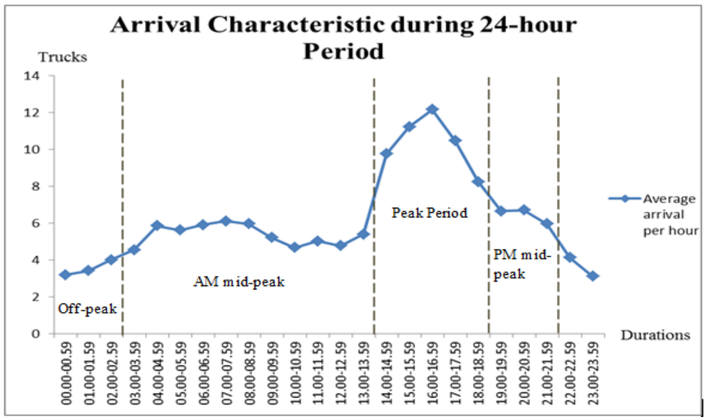

Figure 2. Arrival characteristics of trucks at the cement plant during a 24-hr period.

Table 1. Average truck arrival rate, interarrival time, and total arrival during each phase.

Phase	Average Arrival Rate (trucks/hour)	Average Interarrival Time (minutes)	Average Arrival (trucks)
Off-peak period	3.56	16.84	18
AM mid-peak period	5.37	11.18	59
Peak period	10.37	5.93	52
PM mid-peak period	6.44	9.32	19
Total			148

3.3 Utilization Factor (UF)

The utilization factor was first developed by Singh (1990), and later advanced in Gowda et. al., (1998). Varying constructs of UF can be created for different processes, depending on what parameters are considered important, and what data is available. UF represents efficiency – an output/input function. In this study, UF is a multiplication of proportion of truck productive time per total time of truck and proportion of machine productive time per total machine time, as shown in Eq. (1). The possible range of the utilization factor varies from 0 to 1. Higher values are more favorable.

$$UF = \frac{(\text{TruckTotTime - TruckWaitTime})}{(\text{TruckTotTime})} \times \frac{(\text{MachineTotTime - MachineIdleTime})}{(\text{MachineTotTime})} \qquad (1)$$

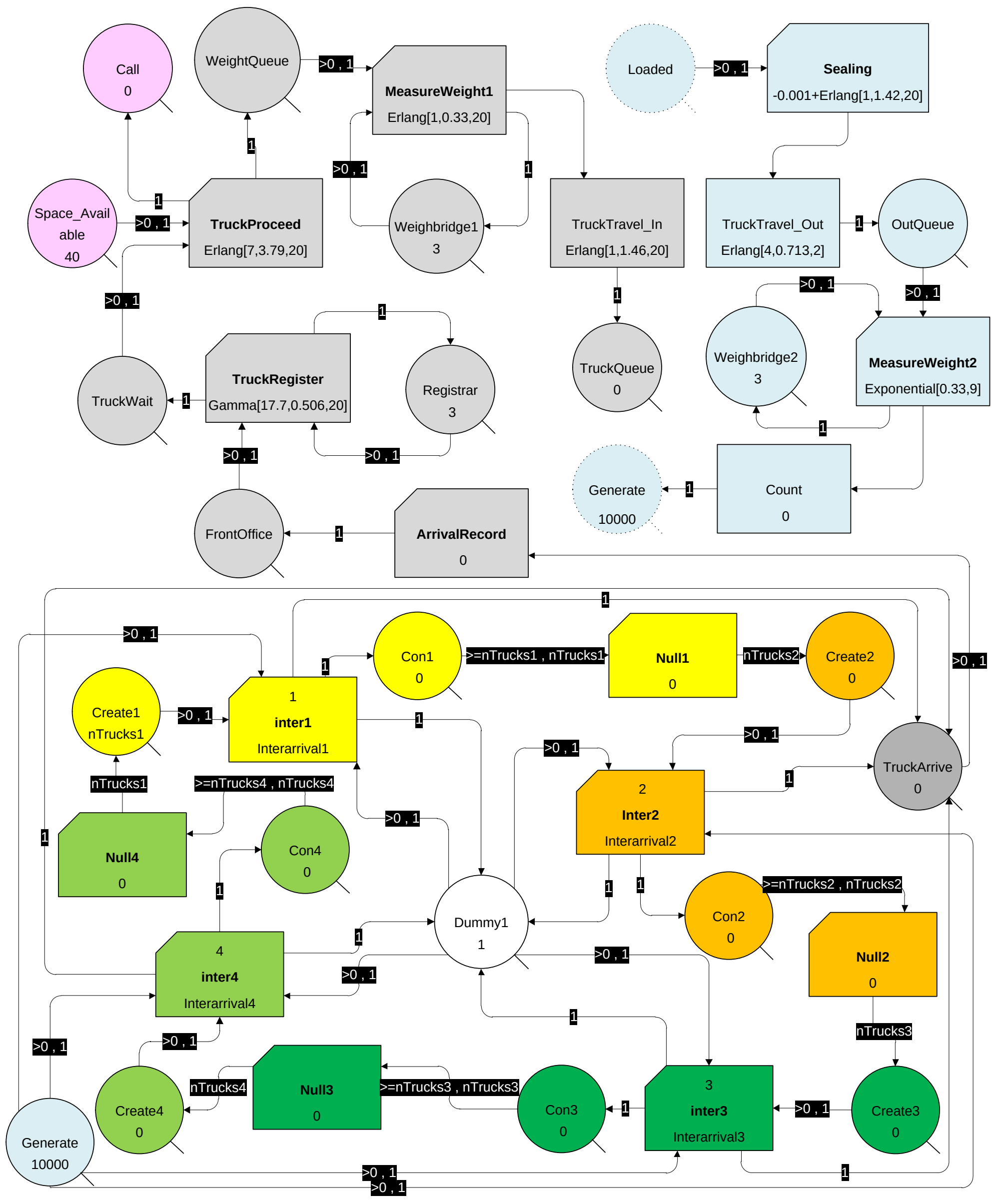

Figure 3. Truck generator model (top) and process model (bottom).

4 SENSITIVITY ANALYSES RESULTS

According to the results and the sensitivity analyses, six models which yield high utilization factor, ranging from 0.474 - 0.501, were selected for further analysis. The six models are: the default model with merged loading queue (merged 4+0); 3 channels with an extra channel during peak duration (3+1); 3 channels with two extra channels during peak duration (3+2); 3 channels with 3 extra channels during peak duration

(3+3); 4 channels with an extra channel during peak duration (4+1); and 4 channels with two extra channels during peak duration (4+2). The results are given in Table 2:

Table 2. Comparison of results among the models of interest.

Number of Machines	UF	% Truck Productive Time	% Machine Productive Time	Total Related Cost (US$)	Waiting Time at site (min)	Total Waiting Time (min)	Total Time of Truck (min)	Loading Time (min)	Avg. Queue Length
3+1	0.486	0.735	0.662	93,520	13.66	14.02	52.87	21.85	1.38
3+2	0.481	0.771	0.624	97,382	11.41	11.78	51.47	22.69	1.15
3+3	0.474	0.791	0.599	101,235	10.37	10.73	51.39	23.66	1.05
4+0(merged)	0.501	0.846	0.592	101,110	6.98	7.32	47.69	23.34	0.71
4+1	0.491	0.893	0.550	104,685	4.48	4.86	45.39	23.53	0.45
4+0(default)	**0.354**	**0.593**	**0.596**	**101,186**	**27.46**	**27.83**	**68.41**	**23.57**	**2.78**
4+2	**0.478**	**0.923**	**0.518**	**108,348**	**3.05**	**3.42**	**44.33**	**23.9**	**0.31**
Change	12.5%	33.0%	-7.8%	7.1%	-88.9%	-87.7%	-35.2%	1.4%	-88.8%

5 DISCUSSION AND CONCLUSIONS

Model 4+2 (Figure 4) yields a percentage of truck productive time, truck waiting time, throughput time, and average queue length of 0.92%, 3.4 minutes, 44.3 minutes, and 0.3 trucks, respectively, the best results among the selected models. Although the higher $108,348 related cost and relatively low percent utilization of machines are induced by model 4+2, the total related cost generated during the 350 days of simulation time exceeds cost from the existing practice by only US $7,162, or only US $20.50 per day, or only 7%. However, the truck waiting time, total time of truck, and average queue length of the model decreases from default model by 88%, 35%, and 89%, respectively; the percent of truck productive time improves by 33%, while the percent utilization of machines decreases by only 7.8%. Thus, the model 4+2 is suggested for making an improvement on the cement-loading process at the plant. This is due to its capability to reduce truck waiting time, throughput time, and queue length, with relatively low additional related costs. The main arbiter, however, is the utilization factor.

To accomplish the 4+2 model, the queuing system of the loading queues needs to be improved by merging queues together as a truck pool, in order to eliminate the imbalance of truck waiting time from multiple queues. In addition, two additional loading channels need to be added daily between 2 PM to 10 PM by assigning channel 25 and channel 26 to operate, with an extra operator per each channel during the period.

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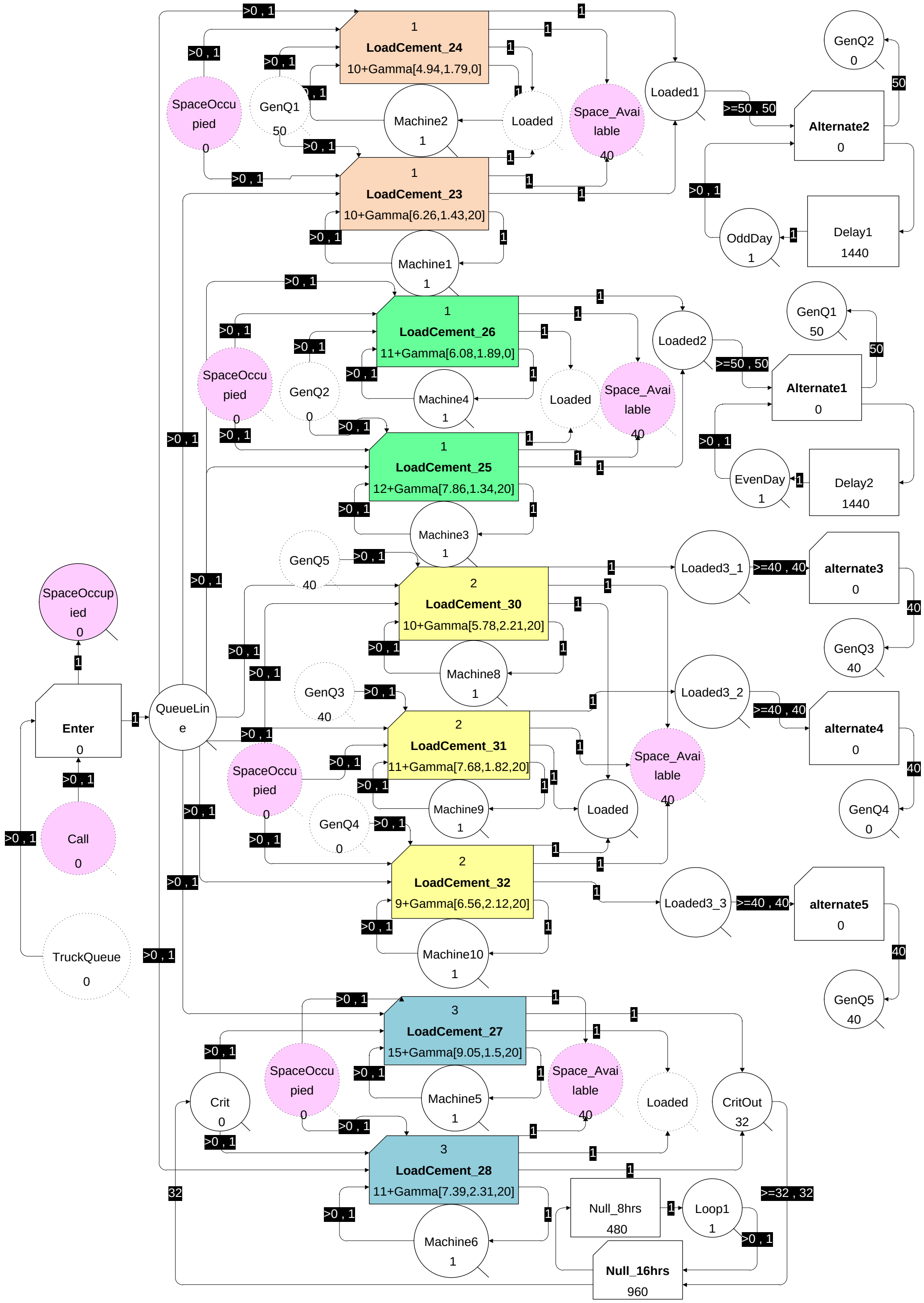

Figure 4. The model of 4 channels with two extra channels during peak duration (4+2).