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OPTIMIZATION OF READY MIXED CONCRETE PLANT OPERATIONS USING SIMULATION TECHNIQUES

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ABSTRACT

The simulation program RMCSIM, developed by the authors, is used to simulate the performance of a ready mixed concrete plant's operation. Results from the simulation reveal that the performance of the concreting operations will not be improved once the optimal truckmixer number is reached even if extra truckmixers are provided. The optimal number of truckmixers can be known from the results of the concreting operation simulation. Another observation is that the performance of the concreting operations at sites is usually worse than that at the concrete plant which provides truckmixers to the former. Moreover, two batching bays in a plant can perform better than one bay in order to help improve the performance of the concrete plant to match the site needs.

KEYWORDS

Batching plant, Simulation, Truckmixer, Ready Mixed Concrete, RMCSIM

1. INTRODUCTION

Ready mixed concrete plants in Hong Kong do not find it easy to match the timing of their concrete deliveries with the needs of their sites served. There are many factors, which can make the scheduling unsatisfactory. The result, in general, is for a concrete pour to be delayed while waiting for the next truckmixer delivery for a part of the time, and yet there is an oversupply for the rest of the time, with truckmixers wastefully queuing to be unloaded on sites.

Data on this situation have been collected (Anson et al., 2002; Ying et al., 2000) in order to understand the scope of the problem and to study how to help minimize the inefficiencies. The data collected are used in this paper to study how the simulation technique can be used to optimize ready mixed concrete plant operations.

RMCSIM is a simulation-modeling program which is developed by the authors of this paper using Visual basic 6.0 and Data base Access, and it is Microsoft based. It can be used to simulate the performance of a concrete batching plant with **M** truckmixers to serve **S** sites, where sites are at variable distances **D** from the plant and variable quantities **Q** of concrete are required by the sites, and the sites use different placing methods to unload the concrete. All these are the variables to be input by the users. The program performs simulation runs after these variables have been input. The objective of this paper is not to discuss the details of RMCSIM but to show the results of the simulations run by the program.

2. METHODOLOGY

Three days of concreting operations are used as the samples to study how different daily site orders, different number of TMs (i.e. truckmixers) used, different combinations of TMs, and different numbers of batching bays in the concrete plant, affect the results. The variables are shown in Table 1a.

Table 1a: Description of Experiment

Day	Volume (m^3) of concrete order	No. of Batching bays	No. of TMs used in simulation run	Combination cases of TMs
1	386 (~ 400)	1	15	A
			20	B
2	545 (~ 550)	2	25	C
			30	D
3	697 (~ 700)		35	E

There are two kinds of TMs, of 5 m^3 and 7 m^3 volumetric capacity. There are five (A, B, C, D and E) combinations of TMs used in the simulation, which are shown in Table 1b.

Table 1b: Arrangement Of Tms in Different Combination Cases

Combination cases of TMs	Arrangement of TMs (capacity of truckmixers in m^3)	Approximate percentage of 5 m^3 TMs
A	5,5,5,5,7,7,5,5,5,5,7,7,………..	67%
B	5,5,5,7,7,5,5,5,7,7,……………	60%
C	5,5,7,7,5,5,7,7,5,5,7,7,………..	50%
D	5,5,7,7,7,5,5,7,7,7,……………	40%
E	5,5,7,7,7,7,5,5,7,7,7,7,………..	33%

Three simulations are run for each combination and their results are averaged in order to make the simulation results more accurate. In table 2a, the first column is the name of the simulation run. For example, ‘d2_15_2a3’ means the simulation run of Day 2 concreting assuming there are 15 TMs of Type A arrangement for a concrete plant of 2 mixing bays and it is the 3rd simulation run. An average is taken after the simulation has been run for three times and it is shown with bolder size in Table 2a. Table 2b shows the performance of batching bay(s). Totally, 450 simulations runs (3 days x 2 bays x 5 TM numbers x 5 TM combination cases x 3 runs for each case = 450) are performed. The results are then stored in the database for printing or for possible further analysis.

Table 2a: Example of Simulation Results (A)

Name	Actual working min of TM	Idle time on plant (min)	% of idle time in the day	TM provision on site/ pour time	No Concrete on Site/ pour time
d2_15_1a1	542.07	175.53	24.52	124	98
d2_15_1a2	525.27	171.47	24.68	126	69
d2_15_1a3	528.73	168.73	24.28	140	79
d2_15_1a	**532.02**	**171.91**	**24.49**	**130.00**	**82.00**
d2_15_2a1	531.27	170.67	24.27	131	108
d2_15_2a2	550.07	165.20	22.90	141	93
d2_15_2a3	535.40	163.20	23.38	123	88
d2_15_2a	**538.91**	**166.36**	**23.52**	**131.67**	**96.33**

Table 2b: Example Of Simulation Results (B)

Name	Total working time of bay no. 1	% of bay no. 1 working	% of bay no. 1 waiting	Total working time of bay no. 2	% of bay no. 2 working	% of bay no. 2 waiting
d2_15_1a1	212	33.33	66.67	0	0	0
d2_15_1a2	210	35.23	64.77	0	0	0
d2_15_1a3	208	35.68	64.32	0	0	0
d2_15_1a	**210.00**	**34.75**	**65.25**	**0.00**	**0.00**	**0.00**
d2_15_2a1	172	28.86	71.14	40	7.18	92.82
d2_15_2a2	170	26.73	73.27	40	7.18	92.82
d2_15_2a3	176	29.53	70.47	34	6.14	93.86
d2_15_2a	**172.67**	**28.37**	**71.63**	**38.00**	**6.83**	**93.17**

3. SIMULATION RESULTS

450 simulation runs are performed and Tables 2a and 2b show 6 of those. Three summary tables are then compiled to show the overall simulation results for the three days. Table 3 is that for Day 2. Three figures 1a, 1b and 1c are plotted to show the summary of the three days performance which is based on the comparison of 'TM provision on site' against 'no concrete on site' whose detail explanation can be found in Anson et al. (2002) or Anson and Wang (1998). The full results are given in a research report (Ying et al., 2002) in which the details of the 450 simulation runs are shown. 'TM provision on site' is the total truckmixer-minutes on site expressed as a % of the duration in minutes of the concrete pour concerned. 'No concrete on site' is the total number of minutes when there is no truckmixer available on site to deliver concrete to the placing gang, expressed as a % of the duration of the pour.

Table 3: Summary Of Day 2 Simulation Results

Name	Actual working min of TM	Idle time on plant (min)	% of idle time in the day	TM provision on site	No Concrete on Site
d2_15_1	346.88	296.70	46.09	136.67	40.67
d2_15_2	357.01	284.10	44.32	140.13	38.20
d2_20_1	314.44	323.48	50.71	132.00	41.60
d2_20_2	315.82	322.36	50.51	127.00	39.00
d2_25_1	250.70	385.87	60.62	128.87	37.80
d2_25_2	253.06	382.99	60.21	125.00	36.27
d2_30_1	210.36	425.72	66.93	130.40	37.80
d2_30_2	207.55	422.70	67.07	130.60	37.20
d2_35_1	179.42	455.30	71.73	132.87	39.53
d2_35_2	179.76	454.95	71.68	133.73	36.33

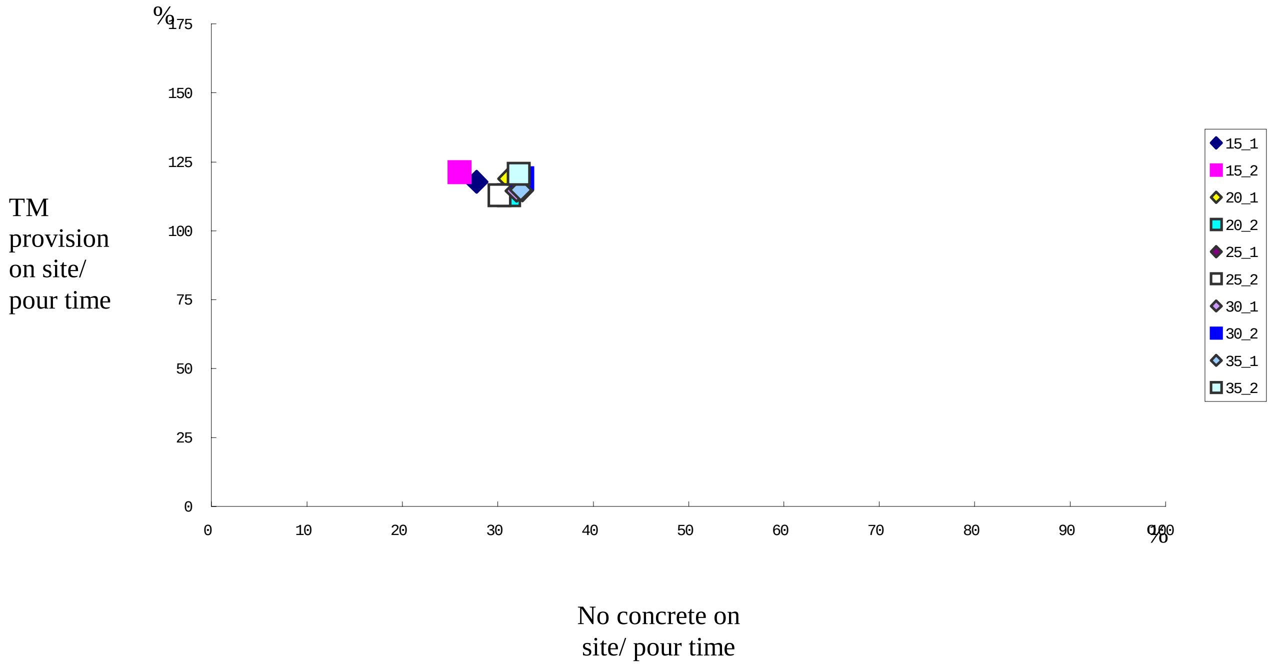

Figure 1a: Day 1 (386 m^3)

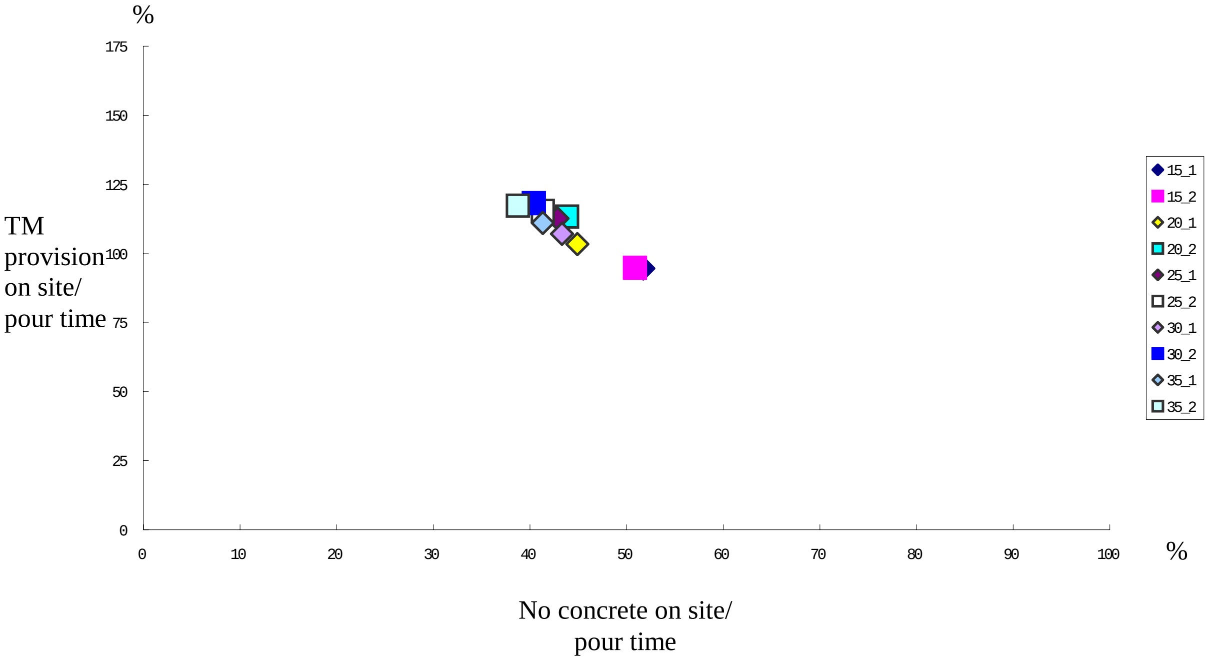

Figure 1b: Day 2 (545 m^3)

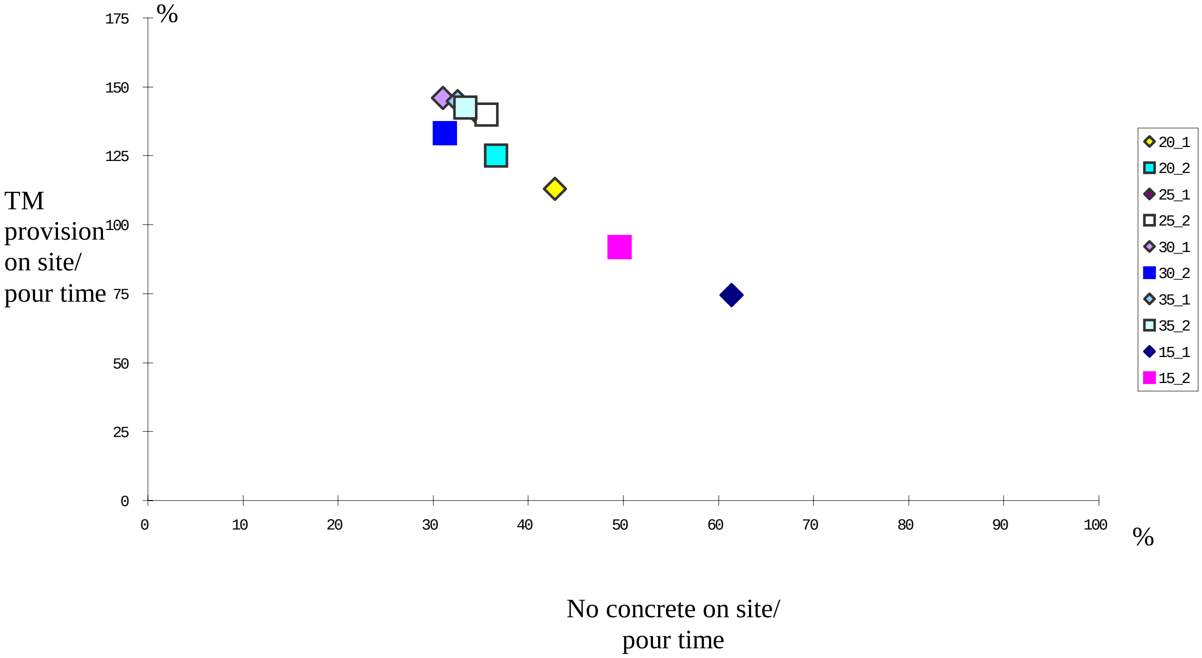

Figure 1c: Day 3 (697 m^3)

Table 4: Comparison of the performance between 15TM, 20TM and 25TM for Day 1

Day 1		Pour time			TM provision on site/ pour time			No concrete on site/ pour time			
Pour no	Volume (m^3)	15 TM	20 TM	25 TM	15 TM	20 TM	25 TM	15TM	20TM	25TM	Improvement
1	88	580	566	537	101.0	105.5	135.6	32.2	29.5	22.2	√
2	90	569	562	546	116.3	159.1	133.0	27.6	24.6	16.5	√
3	45	511	497	474	49.5	54.5	55.5	71.0	69.4	68.6	2
4	14	66	69	71	63.6	42.0	71.8	66.7	81.2	63.4	2
5	85	551	519	569	55.9	57.2	53.1	69.1	74.0	74.3	2
6	2	10	8	19	190.0	162.5	142.1	20.0	0.0	47.4	1
7	121	534	486	506	91.6	86.2	100.0	57.1	58.0	58.5	
8	2	15	17	15	140.0	158.8	173.3	0.0	0.0	0.0	
9	33	249	216	215	92.4	95.8	77.7	59.4	41.2	58.6	2
10	1	25	18	26	136.0	105.6	57.7	20.0	55.6	73.1	1
11	12	156	135	247	20.5	28.1	20.2	90.4	89.6	91.9	2
12	3	12	16	24	125.0	150.0	112.5	16.7	12.5	45.8	
13	2	28	21	5	39.3	95.2	220.0	82.1	52.4	0.0	1
14	6	129	10	13	31.8	110.0	153.8	89.9	50.0	61.5	1
15	5	40	13	23	65.0	146.2	87.0	62.5	23.1	52.2	1
16	2	50	25	27	58.0	56.0	70.4	72.0	48.0	63.0	
17	22	238	162	169	70.6	85.2	71.6	57.1	43.2	49.7	
18	3	55	9	19	56.4	233.3	100.0	65.5	0.0	47.4	1
19	9	100	36	30	111.0	116.7	183.3	39.0	30.6	13.3	1
Sum		3918	3385	3535	-	-	-	-	-	-	
Average		-	-	-	84.9	107.8	106.2	52.6	41.2	47.8	

Remarks: √ means improvement when number of TM increase
1 means irregular fluctuation
2 means serious case of no concrete on site

4. FINDINGS AND CONCLUSIONS

- 'No concrete on site' is improved when two batching bays are used instead of one. Take Day 3 as an example (see Fig. 1c). The improvement in 'no concrete on site' is 12% from 'd3_15_1' to 'd3_15_2". This 12%, so happened, is the maximum value resulted from all the simulation runs. (The improvement in fact ranges from 0% to 12%). This means that 3.5 minutes on average is improved for each trip if 15 truckmixers are available for concrete delivery, as there are 120 trips on that day. The sites spend 3.5 minutes less in waiting for the truckmixers to come to provide concrete, for each truckmixer trip on this day, if the plant has two batching bays instead of one. A significant improvement from 1 bay to 2 bays can be achieved if insufficient truckmixers are used for concreting a larger order volume. The above is an example. Improvement can also be found, although to a less extent, even if sufficient numbers of truckmixers are available. Figure 1c shows the two cases of (1) 15 truckmixers used on Day 3 (representing insufficient truckmixers), and (2) 30 truckmixers used on Day 3 (representing sufficient truckmixers). Readers can see from Fig. 1c that in Case (1), 12 % of improvement on the value of 'no concrete on site' has been achieved, representing a significant improvement, while in Case (2), only 2% of that has been improved, representing a less significant improvement.

- An optimal truckmixer number can be found from the simulation. Extra truckmixers beyond the optimal number seldom help reduce 'no concrete on site'. 15 truckmixers are sufficient to serve Day 1 needs (see Fig. 1a) as 15 truckmixers can provide good services for a day that needs only 400 m^3 of concrete. 'No concrete on site' has not been reduced if 35 truckmixers are used for Day 1. Day 2 simulation shows that the optimal number of truckmixers is about 20, and Day 3 about 25. Not much improvement can be found if extra truckmixers are used.

- Large pours (>80 m^3) can be improved when a large number of truckmixer is used but small pours (<80 m^3) do not. Improvement is shown in Table 4 that 'no concrete on site' for, say, both Pour 1 and Pour 2, differs by about 10% for cases of 15 number and 25 number of truckmixers, and this is represented by the remark √ in the table.

- Irregular fluctuation is shown for certain small pours on 'no concrete on site' in Table 4, which is represented by remark 1. The fluctuation usually occurs at small pours only, because if the pour time (which is a denominator of the formula) is small, slight incremental pour time will affected the 'TM provision on site' and 'no concrete on site enormously. (Y-axis = TM provision on site / Δ pour time, and X-axis = no concrete on site / Δ pour time)

- Serious case of 'no concrete on site' is also shown in Table 4, which is represented by remark 2. Such bad performance occurs when the wrong time interval between truckmixer arrivals is predicted by the site. The concrete plant follows the instruction given by the site to deliver concrete to match the site needs. Because of the wrong prediction, the site waits for a very long time before the truckmixer arrives, so that a serious case of 'no concrete on site' occurs.

- From all the three figures, the plots are below 150% on 'TM provision on site' for most of the time, while they are over 30% on 'no concrete on site' for most of the time. A target to aim for, as suggested by the authors, is 150% and 10% respectively for the plot. Therefore, it can be concluded that most problems of the mismatch affect the sites rather than the concrete plants. Hence, more efforts should be applied to studying how to reduce the waiting for concrete on site, without excessively increasing the truckmixer provision.

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