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AUTOMATIC DATA COLLECTION TO IMPROVE READY-MIXED CONCRETE DELIVERY PERFORMANCE

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ABSTRACT: Optimizing truck dispatching-intervals is imperative in ready mixed concrete (RMC) delivery process. Intervals shorter than optimal may induce queuing of idle trucks at a construction site, resulting in a long delivery cycle time. On the other hand, intervals longer than optimal can trigger work discontinuity due to a lack of available trucks where required. Therefore, the RMC delivery process should be systematically scheduled in order to minimize the occurrence of waiting trucks as well as guarantee work continuity. However, it is challenging to find optimal intervals, particularly in urban areas, due to variations in both traffic conditions and concrete placement rates at the site. Truck dispatching intervals are usually determined based on the concrete plant managers' intuitive judgments, without sufficient and reliable information regarding traffic and site conditions. Accordingly, the RMC delivery process often experiences inefficiency and/or work discontinuity. Automatic data collection (ADC) techniques (e.g., RFID or GPS) can be effective tools to assist plant managers in finding optimal dispatching intervals, thereby enhancing delivery performance. However, quantitative evidence of the extent of performance improvement has rarely been reported to data, and this is a central reason for a general reluctance within the industry to embrace these techniques, despite their potential benefits. To address this issue, this research reports on the development of a discrete event simulation model and its application to a large-scale building project in Abu Dhabi. The simulation results indicate that ADC techniques can reduce the truck idle time at site by 57% and also enhance the pouring continuity in the RMC delivery process.

Keywords: Automatic data collection; RMC delivery process; Simulation; Truck dispatching intervals

1. INTRODUCTION

Ready-mixed concrete (RMC) is a quickly perishable product that has to be produced on -demand and delivered at the construction sites within strict time -windows [1]. The use of out-of-date material can result in a poor quality structure. Furthermore, the contractor (or client, depending on the contract type) incurs the cost of wasted the material and embraces the additional burden of resultant delay and idle resources awaiting the next concrete delivery [2].

To ensure efficient RMC delivery between concrete plant and construction sites, it is important to find optimal dispatching intervals in the delivery process. Intervals shorter than optimal may induce queuing of idle trucks at a construction site, resulting in a long delivery cycle time. On the other hand, intervals longer than optimal can trigger work discontinuity due to unavailable trucks where required. Therefore, the RMC process should be systematically scheduled by identifying the optimal dispatching intervals that minimize waiting trucks as well as guarantee work continuity.

Currently, the dispatching interval decisions are usually made by relying on the site managers' past experience and this often leads to high operational cost and low efficiency.

It is challenging to find optimal intervals particularly in urban areas, due to variations in both traffic conditions and concrete placement speed at the construction site. If managers can access information regarding trucks' status and locations, they could adjust the trucks' dispatching intervals to match the pouring production rate, and ultimately enhance the efficiency of the RMC placement operations. These managerial actions can minimize operation time and consumption of the expensive resources. But a significant amount of data is required for determining real-time trucks' status, and the traditional means for obtaining data, like stop watch, is time-consuming, labor-consuming and error-prone. GPS, RFID and other automated data collection (ADC) techniques can provide a solution to this problem.

In general, concrete plants are not widely using ADC technology because there is a lack of strong statistical evidence of its benefits, and because of the high costs of these required equipments. For this reason, this research aims at measuring the impact of ADC techniques on the RMC delivery performance.

2. LITERATURE REVIEW

A great deal of research has addressed the poor performance of RMC supply processes. For example, a survey in Hong Kong [3] revealed that only 17% of RMC pours were classified as cost efficient, and that 38.7% of trucks' operations time was spent idling.

To address this problem, many studies (including [4], [5] and [6]) have applied simulation approaches to analyze the RMC delivery process. [7] investigated sensitivity parameters in resource combinations, including the number of truck mixers, buckets and labourers in concrete placing crews, and concluded that they were important to RMC delivery performance. However, assigning additional resources increases the cost of the operations, which is another aspect of concern for construction managers. Accordingly, increasing the resources quantity is not an advisable way to improve the operation performance.

Fattah and Ruwanpura [8] proposed that the factors than impact the duration of a concrete pouring operation include: number of concrete trucks; capacity of concrete trucks; trucks speed (emptying and loading); number of batch plants available; batch plant production rate; distance between the construction site and the concrete batch plant; number of concrete pumps; concrete pump's production rate. Among these factors, the delivery trucks' arrival pattern was established as the most influential factor over the productivity of the RMC placing equipment. This is especially true for arrivals early in the operation. A case study in Singapore [5] found that the optimal inter-arrival time of trucks for pumped pours was 11 minutes. Using this inter-arrival time could reduce the average number of trucks queuing on site to only two while maintaining the utilization of pumping equipment at a relatively high level of 92%. Lu and Lam [9] proposed that optimization analysis can be performed to fine-tune the inter-arrival time for each site within a certain limit of the original estimates. As a result, an optimizing guide can be derived to assist the plant operator in prioritizing site demands and marshaling the truck fleet more efficiently, thereby minimizing truck queuing time and crew idle time on all the sites being served. The system performance is expected to be sensitive to adjustments on truck inter-arrival times. That is, the operation completion time increases rapidly as the pump or inter-arrival time is increased. This is not a linear relationship [6]. Srichandum and Rujirayanyong [10] developed a model based on Bee Colony Optimization (BCO) in order to find the optimal dispatching schedule to minimize the total waiting time of RMC trucks at construction sites; however the research was on the basis of unknown traffic condition and estimated travel time. Smith [6] used a discrete event simulation model to explore the impact of variations in interval time and pump time, and to maximize the utilization of the plant and minimize the duration of the operation. Park [11] found that under a fixed dispatching interval, the unloading speed at site have s significant and direct impact on the RMC delivery performance. Moreover, it was found that when a longer dispatching interval is adopted traffic conditions will also impact this process.

Given the importance of communication in construction management, previous research studied ADC systems and applied these in supply chain management within the construction industry. Wang [12] applied a mobile construction RFID-based dynamic supply chain management (M-ConRDSCM) system which enables the information flow among offices and construction sites in a supply chain environment. Moon [13] developed a ubiquitous concrete pour monitoring system (u-CPMS) to keep track of the progress of concrete pouring through wireless internet, and to make decisions on the batch intervals of trucks. Technique recommendations for the ADC system design were also provided including GPS, RFID, and network.

This paper will demonstrate the benefit of the ADC system, and the resulting improvement in RMC delivery performance through use of a simulation model. For this purpose, we first introduce the RMC operation process and simulation approach applied in this paper. Two DES simulation models are then developed to mimic operations: the first without access to information regarding trucks' statuses and the second than dose access trucks' statuses information. Finally, the two models' simulation results are compared to illustrate that the automated data collection system can be helpful in improving the performance of RMC delivery.

3. FACTORS THAT CAN IMPACT DISPATCH SCHEDULE

In view of the complexity, uncertainty and variability in RMC delivery operations, optimization of inter-arrival times for all sites assists in generating an optimal concrete production schedule. An optimal schedule can significantly enhance the performance of a concrete plant, by utilizing the trucks available to meet demands from site clients [9].

There are tradeoffs between the trucks' dispatching intervals and inefficiencies such as waiting time or crews' idle time at the pouring site. If the intervals are too short, redundant trucks are sent to the site, and this will lead to queue of trucks waiting at the pouring site. Such conditions can even cause deterioration in traffic conditions, which may in turn delay the delivery time. On the other hand, if the intervals are too long, this will result in a shortage of trucks, pouring interruptions and idle site-resources (e.g., concrete pump or labors).

The interval time is largely governed by: the availability of plant resources; traveling distances/ travel times from the plant to each site; contractors' placement methods and particular pour-start schedules and progress rates on each pour; and the subtle interactions between these factors [14]. Various construction sites in different cycles will require varying dispatching intervals. The intervals should be adjusted according to real-time pouring rates and traffic conditions. Using the ADC system, real-time information pertaining to traffic conditions on the delivery route could be sent to the concrete plant where managers are able to adjust the dispatching intervals.

(1)The travel time between the RMC batch plant and the construction site is determined by the distance between these locations, and the speed of the RMC delivery truck (which is partially determined by the traffic conditions). Among these, distance can be determined; and the speed is also straightforward to predict [10]. Complex traffic condition is the element of travel time prediction that is difficult to quantify and forecast.

Therefore, traffic conditions are crucial in finding an optimal interval. If the traffic conditions detected by an ADC system are poor, the delivery time duration will be longer than average. The next cycle dispatching interval can then be revised to dispatch earlier and ensure the delivery is on time without process interruptions and crew idle time. On the other hand, if there is minimal traffic on the delivery route, the delivery time for the next cycle can be forecasted to be shorter. This information would also be sent to the plant, and in this way, the manager is able to change the dispatching interval so that the next truck will be dispatched later to minimize the queuing of trucks on site.

(2) Pouring speed is another key factor in determine optimal dispatching intervals. The duration of RMC pours at the construction site depends on the construction methods and elements used, and this duration can affect the optimal dispatching interval [10]. The progress rate can be collected and reported to central plant. Using real-time information on pouring rates, the interval can be adjusted as appropriate to match the updated pouring rate.

Therefore, these two factors are the key constraints in RMC delivery productivity. Adjusting the dispatching intervals can reduce the level of negative impacts resulting from these constraints. However, due to the complexity and unpredictability of traffic conditions and pouring speed, it is impossible to find a fixed optimal dispatching interval. The ADC system, in form of RFID and GPS technologies, provides a solution to this problem. When the real-time information regarding on traffic conditions and pouring speed are available, the decision-makers can generate variable dispatching schedule according to ongoing progress. In the following sections, this paper will focus on the benefits that variable dispatching intervals bring about for delivery performance.

4. EVALUATION OF RMC DELIVERY PERFORMANCE

4.1 Minimizing trucks' idle time at site

Lean production theory interprets the production system as a series of conversions and flows. Conversions activities are the activities that add value to the final product. One of the principles of the lean production theory is to eliminate or reduce the non value-adding activities [15]. In the RMC delivery process, trucks' waiting time at the pouring sites contributes no value to the final product, but only increases the risk of poor concrete quality and operation time; therefore this waiting time should is to be considered as a important performance evaluation criterion. Also, reducing the operation time is another objective for improving RMC delivery performance that can minimize the risk of poor quality concrete.

Table 1 Data collection Sheet

4.2 Maintaining job continuity, without disruption

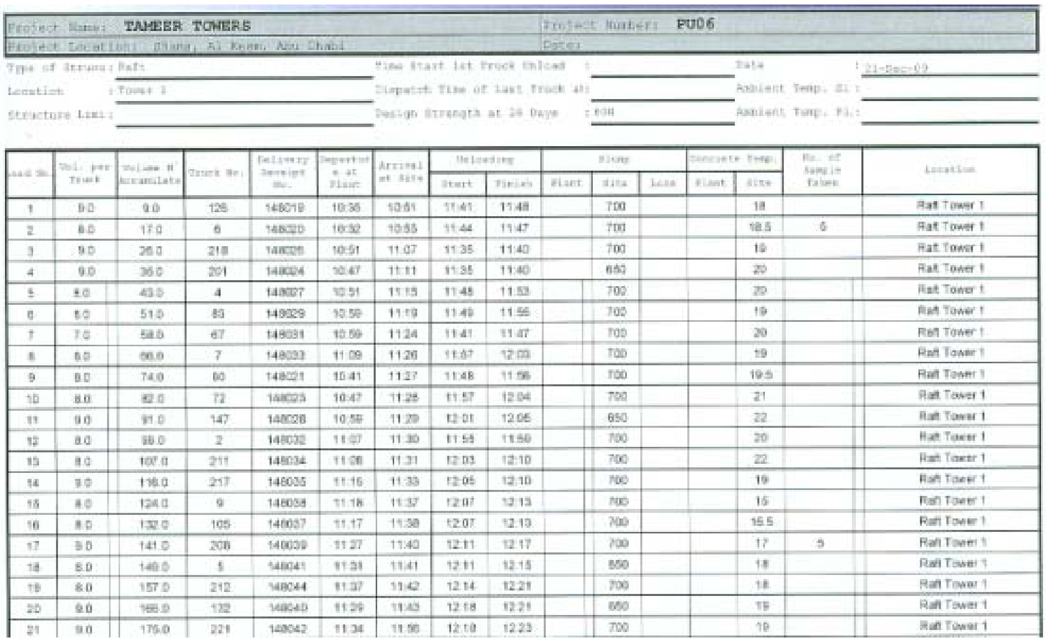
On–time delivery of RMC is essential to a contractor. If a truck is late, the crew may stand by, leading to a waste of human resources. Even worse, the cumulative interruptions of concrete supply may cause a delay to the whole project.

5. CASE EXAMPLE

Data used in this research was collected in a major civil engineering project in Abu Dhabi (United Arab Emirates). All the concrete production and delivery was provided by a selected concrete company. Data collection was under taken by two groups at the site during concrete pouring. Trucks arrived at site with information including time of departure and concrete loading time as well as temperature and initial slump at plant.

Based on this information the trucks' times of arrival, the travel time, loading, waiting to unload and unloading time of each truck was calculated. Data relating to a 20 hour sample of a slab pouring operations was collected. The total accumulated volume of concrete at the completion of this data is 4147m³. 84 trucks carrying on 502 delivery cycles were investigated. 5 pumps were employed in this pouring site. Part of the original data collection sheet is showed in table 1.

Activities durations were fitted to selected probability distributions, which are shown in Table 2, based on the raw data collected in project. Statistical software EasyFit was utilized to fit the data into probability distributions and estimate parameters that best fit the statistical properties of the collected data. The travel time distribution and unloading time distribution are compared with the real data in Figure1.

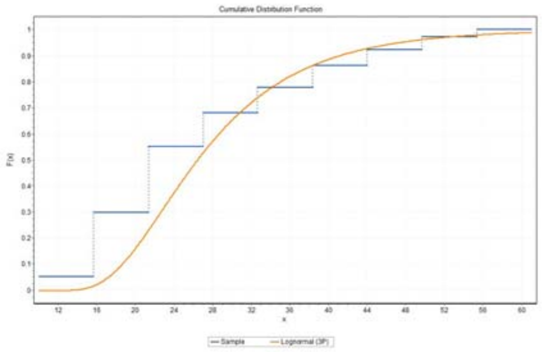


Project Name: TAMEER TOWERS		Project Number: PU06	
Project Location: Shams, Al Reem, Abu Dhabi		Date:	
Type of Struct.: Raft	Time Start 1st Truck Unload :	Date : 21-Dec-09	
Location : Tower 1	Dispatch Time of Last Truck at:	Ambient Temp. St.:	
Structure Lmt.:	Design Strength at 28 Days : 60N	Ambient Temp. Fi.:	

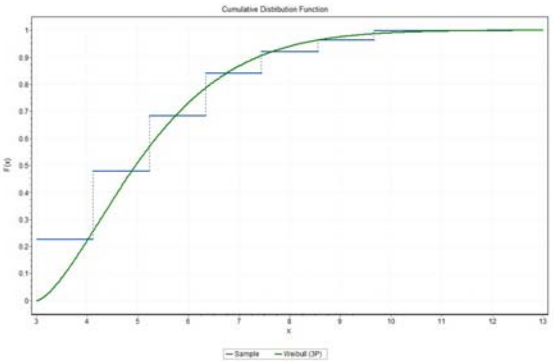
Load No.	Vol. per Truck	Volume M³ Accumulate	Truck No.	Delivery Receipt No.	Departure at Plant	Arrival at Site	Unloading		Slump			Concrete Temp.		No. of Sample Taken	Location
							Start	Finish	Plant	Site	Loss	Plant	Site		
1	9.0	9.0	126	148019	10:36	10:51	11:41	11:48		700			18		Raft Tower 1
2	8.0	17.0	6	148020	10:32	10:55	11:44	11:47		700			18.5	5	Raft Tower 1
3	9.0	26.0	218	148026	10:51	11:07	11:35	11:40		700			19		Raft Tower 1
4	9.0	35.0	201	148024	10:47	11:11	11:35	11:40		650			20		Raft Tower 1
5	8.0	43.0	4	148027	10:51	11:15	11:48	11:53		700			20		Raft Tower 1
6	8.0	51.0	85	148029	10:59	11:19	11:49	11:56		700			19		Raft Tower 1
7	7.0	58.0	67	148031	10:59	11:24	11:41	11:47		700			20		Raft Tower 1
8	8.0	66.0	7	148033	11:09	11:26	11:57	12:03		700			19		Raft Tower 1
9	8.0	74.0	60	148021	10:41	11:27	11:48	11:56		700			19.5		Raft Tower 1
10	8.0	82.0	72	148025	10:47	11:28	11:57	12:04		700			21		Raft Tower 1
11	9.0	91.0	147	148028	10:59	11:29	12:01	12:05		650			22		Raft Tower 1
12	8.0	99.0	2	148032	11:07	11:30	11:55	11:59		700			20		Raft Tower 1
13	8.0	107.0	211	148034	11:08	11:31	12:03	12:10		700			22		Raft Tower 1
14	9.0	116.0	217	148035	11:15	11:33	12:05	12:10		700			19		Raft Tower 1
15	8.0	124.0	9	148038	11:18	11:37	12:07	12:13		700			15		Raft Tower 1
16	8.0	132.0	105	148037	11:17	11:38	12:07	12:13		700			15.5		Raft Tower 1
17	9.0	141.0	208	148039	11:27	11:40	12:11	12:17		700			17	5	Raft Tower 1
18	8.0	149.0	5	148041	11:31	11:41	12:11	12:15		650			18		Raft Tower 1
19	8.0	157.0	212	148044	11:37	11:42	12:14	12:21		700			18		Raft Tower 1
20	9.0	166.0	132	148040	11:29	11:43	12:18	12:21		650			19		Raft Tower 1
21	9.0	175.0	221	148042	11:34	11:56	12:18	12:23		700			19		Raft Tower 1

Table 2 Probability Distributions as Model Input

Activity	Distribution
Dispatching interval	Triangular(0,4.5,2.5)
Travel time	Lognormal(2.8,0.5,10)
Unloading time	Weibull(1.93,3.58,8)



(a) Travel time duration CDF



(b) Unload time duration CDF

Figure 1 Comparison of real data and generated distribution

6. SIMULATION MODEL

This research utilizes simulation experiments in order to make better decisions with the objective of increasing efficiency and reducing costs [16]. In order to examine the benefits of the ADC techniques, a simulation model is developed. With a focus on the dispatching intervals, allowing changes in the intervals at discrete points, a discrete-event simulation approach is adopted and Anylogic software is used to build the RMC delivery process model.

6.1 Base model

To illustrate the improvement induced by using ADC technologies, a base model is developed represents current practice, where plant managers have limited access to information regarding traffic and site conditions. In this model, concrete is produced at batch plant. Only when a truck and an order are both available, can a duty-cycle of concrete delivery begin. Without information about the traffic and site conditions, the dispatch intervals triggered by the arrival of the order are usually made based on previous performance and manager's intuition.

Trucks depart from site and head towards the construction site, where they queue until the pump is available and they can unload. A queue may or may not be developed before unloading begins. After the concrete is unloaded, trucks return to the batch plant and await the next duty-cycle. The pump continuously pours the concrete, because if this is not the case, the work will be disrupted. The components of the base model and their respective roles are explicated below. Figure 2 shows the RMC delivery model in Anylogic environment.

Source

Sources are responsible for generating entities. In this model sources include truck, pump and order.

Delay

Delays are activities that seize entities for a given amount of time. The delay time is evaluated dynamically, and may be either deterministic or stochastic. Activities in the RMC process used in this model are load, haul, unload, and Return.

Queue

A queue is storage of entities waiting to be served by the following delay in the process flow. Some delays may be related to the condition of other activities, e.g., load and unload are always behind a queue.

In this model, the haul time, unloading time, and return time are stochastic and represented by probability distributions which originate from the raw data collected from the project.

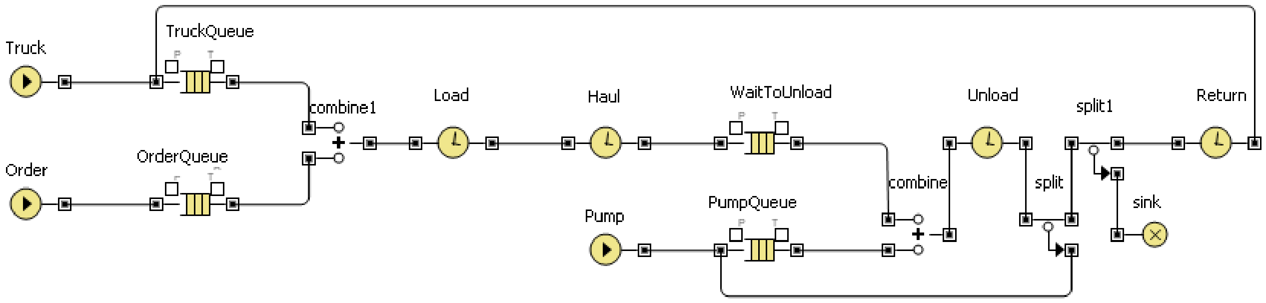


Figure 2 RMC Delivery Model

6.2 Model validation

In order to validate this simulation model and to further demonstrate simulation-based optimization analysis, the model was used to simulate actual RMC delivery processes, so that a comparison could be drawn between the real data collected at the sites and simulation outputs. First loading time, delivery time, pour time, and return time are inputs for the model. The simulation was run through 1000 iterations, with outputs including total operation time (TOT), average truck waiting time (ATWT) at site and average duty-cycle of truck (ADCT) including travel, wait and unload time. These outputs were compared with the equivalent measurements observed at site, as shown in Table 3. This comparison reveals that the simulation results similar to the data collected at the pouring site, illustrating that the simulation results are reliable. Thus, this model can be used to examine the impact of ADC techniques.

Table 3 Comparison of collected data and simulated output

Output	**Real data(A)**	**Simulated Output(B)**	**Difference**
TOT (min)	1180	1196	1.3%
ATWT (min)	6.27	6.13	2.2%
ADCT(min)	46.6	47.7	2.3%

*TOT: Total Operation Time
ATWT: Average Truck Waiting Time
ADCT: Average Duty Cycle Time
Difference=|B-A|/A×100%

6.3 Automatic Data Collection Model

An Automation Data Collection Model was developed using the base model as a foundation. As stated above, the dispatching schedule is closely related with traffic conditions and pouring speed in RMC delivery process. This model was used to demonstrate how constraints in the process can be removed by the incorporation of an ADC system, in the form of RFID, GPS and other sensor technologies.

The dispatching schedule is made without considering variations in delivery time and pouring speed. This fixed dispatching interval may lead to early or late arrivals of trucks from time to time and induce issues around low productivity or poor quality. If the dispatch schedule can be adjusted according to real-time traffic conditions, pouring speed and the queue status at site, work interruptions and long waiting times can be avoided. Such a flexible dispatch schedule cannot be implemented without the support by real-time information. The simulation model replicating Automatic Data Collection is based on the premise that RFID and GPS would collect the data concerning traffic and pouring speed and sent them to concrete plant managers.

The structure of the automatic data collection model is the same as that of the base model with the exception of the dispatching interval structure. The trucks' dispatching intervals are continuously optimized by closely monitoring real-time data collected from trucks in the delivery cycle and those queuing at the site through RFID and GPS. When the number of trucks queuing prior to pouring and the number in delivery are less than a control threshold, an order will arrive at the plant; conversely, when this number is more than a control threshold, orders will be postponed. For every interval, the model assesses whether the quantity of trucks in the traffic and waiting queue is satisfying the control range. In this way, the number of trucks in the waiting queue can be maintained at an acceptable level and continuous pouring process can also be achieved.

7. SIMULATION RESULTS ANALYSIS

To measure the benefits bring about by ADC techniques, it is first verified that an optimal fixed dispatching interval is not a reasonable solution. This is followed by discussion of the simulation results from flexible intervals in terms of impacts on the delivery performance.

7.1 Fixed dispatch intervals

Firstly, data from the real project applied to the base model with fixed intervals to obtain realistic results. Table 4 displays the results of using fixed intervals; and shows that the optimal dispatching intervals are between 2.2 and 2.4 minutes. Using 2.2 minutes as a dispatching interval can complete the delivery process in a short time duration and maintain a high pump utilization, but lead to a long trucks' waiting time at site for about 12 minutes. Enlarge the dispatching interval enable shorter waiting times but prolong the total time and decrease the pump utilization rate. So, it is hard to get an optimal performance by using a fixed interval.

Table 4 Fixed Intervals in Base Model

Fixed intervals (min)	**Avg truck waiting time at site (min)**	**Pump utilization rate (%)**	**Total time (min)**
Real case	6.27	N/A	1180
1	102.25	97.8	1161.64
2	58.28	97.7	1161.39
2.2	12.15	97.3	1166.81
2.3	2.86	94.2	1197.67
2.4	1.43	90.1	1245.52
3	0.21	73.1	1543.79

The variation of uncertainties, including pouring time and delivery time, are then taken into consideration. Variations in delivery time would have a marginal impact on the trucks' waiting times and total time if the delivery time if the delivery trucks were over supplied and if the queue at site offset the variation in the delivery time. However, if there were less delivery trucks deployed in this operation, the variations in delivery time would have a significant impact on the delivery process, as there would be no trucks to play a buffer role. Furthermore, the pouring time variations lengthen the trucks' waiting times at site and operation time.

Therefore, when traffic conditions and pouring rates vary, a fixed optimal truck dispatching interval is far from getting optimal performance.

7.2 Comparison of the simulation results

To obtain optimal performance, the impacts of flexible dispatching intervals are further explored. The operational performance improvement induced by flexible dispatch intervals was evaluated from two aspects by comparing the simulation results of the basic model and ADC model.

(1) Can flexible dispatch intervals minimize waiting time at site and the operation time?

The schedule performance improvement was measured by comparing average waiting time and average operation time in two models. We define the operation time as that between departure from the plant and departure from site, and this includes delivery time, waiting time and unloading time. Table 5 shows a comparison of the simulation results under fixed intervals and flexible intervals. Because different fixed intervals and control sizes in flexible intervals will lead to different total time, duration savings were compared under the same required total time. The results show that the trucks' waiting time at site can be dramatically decreased by approximately 57% by flexible dispatching intervals. Operation time was decreased by approximately 12% when the minimum total time was used. When total time was prolonged, wait time and operation time reductions were lower. The reason for this result is that ADC model removes the buffer queue at the site which is no longer required due to timely information notification and flexible dispatch.

Table 5 Waiting Time and Operation Time Comparison

Model	**Case**		**Total time(min)**	**Avg Waiting time at site (min)**	**Avg operation time (min)**
Base model	Fixed interval (min)	2.2	1166.8	12.16	53.86
		2.3	1197.7	2.86	44.28
		2.4	1245.5	1.43	42.49
ADC model	Control size	15	1165.3	5.18	46.99
		13	1204.3	1.96	43.25
		12	1258.5	1.03	41.97
Total time around 1166				Waiting time saving 57.4% Operation time saving 12.8%	
Total time around 1200				Waiting time saving 31.5% Operation time saving 2.3%	
Total time around 1250				Waiting time saving 28.0% Operation time saving 1.2%	

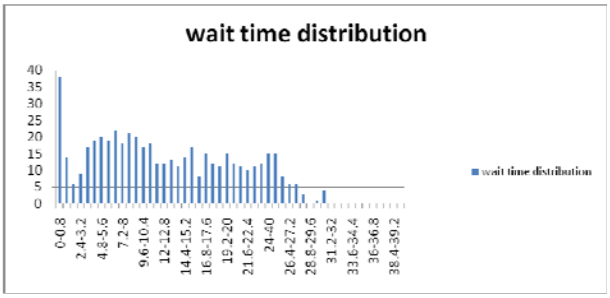
Figure 3 illustrates that there is a clear difference in waiting time at the site between the base model and the ADC model when total time is around 1166 minutes. In the base model (fixed dispatching intervals) the maximum waiting time is about 32 minutes, and the number of cycles of the minimum value group below 0.8 minutes is 38. Whereas, in ADC model (flexible intervals) the maximum waiting time is 16 minutes, and the number of cycles of the minimum value group below 0.4 minutes is 71. Thus, it can be concluded that flexible dispatching intervals can effectively reduce the waiting time and operation time especially when the delivery process needs to be completed within as quickly as possible.

(2) Can flexible dispatching intervals improve performance in terms of maintaining continuous pouring?

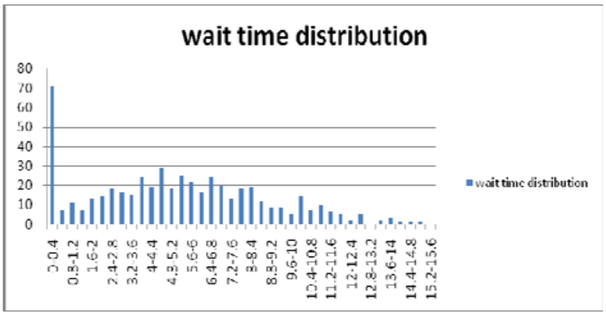
Saving trucks' waiting time before pouring and the operation time are two aspects of improving RMC delivery performance. In addition to this, working continuity is essential (maintaining pump utilization at a high rate).

It can be seen in Table 6 that there is a negligible difference between pump utilization rates in two models, and the utilization rate in the ADC model is slightly higher than that in the base model. Furthermore, the graphs in figure 4 show the trend of pump utilization in base model and ADC model, and it is clear that both of the graphs ascend rapidly initially, and then level at a value approaching 100% utilization. The pump utilization rate in the ADC model climbs faster than that in the base model. This reveals that all the pumps can be utilized sooner using the flexible dispatch schedule.

Flexible dispatching intervals can reduce the wait time at site and also maintain pump utilization at a high rate. Because the data collection system can inform the plant operator about the real-time status at site, trucks' highly demanding statuses and idle statuses can be avoided to bring a steady flow of continuous work.



(a) Base Model (average waiting time is 12.16min)



(b) ADC Model (average waiting time is 5.18min)

Figure 3 Waiting time distribution in two models

Table 6 Pump Utilization Comparison

Base Model	**Intervals size(min)**	**Pump utilization rate**
	2.4	90.1%
	2.3	94.2%
	2.2	97.3%
ADC Model	**Control size(trucks)**	**Pump utilization rate**
	12	90.5%
	13	94.5%
	15	97.5%

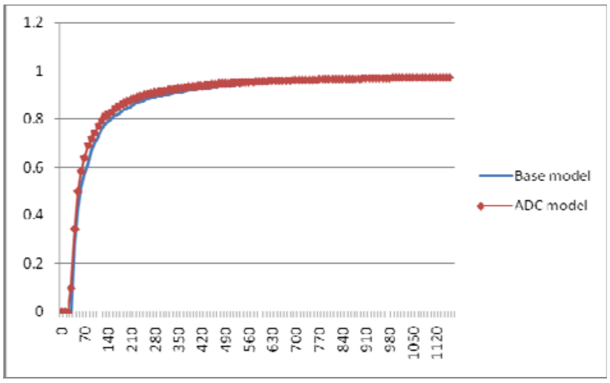


Figure 4 Pump utilization rates in process

8. CONCLUSIONS

This paper presented the benefits for RMC delivery performances expected by ADC techniques. Determining optimal dispatch intervals is important optimizing the performance of the RMC delivery process. It was found that fixed dispatching intervals do not guarantee optimal performance due to complex traffic conditions and varying pouring speed. The ADC techniques allow visibility of this information throughout the process. A discrete-event simulation model was developed and it demonstrated that a fixed dispatching interval cannot guarantee optimal performance. A further modified model to mimic a flexible dispatching intervals case illustrated superior performance in terms of minimizing the trucks' waiting time at site and guaranteeing an improves level of work continuity.

From the results of these two simulation models, it can be concluded that an ADC model that allows for flexible dispatching intervals has the potential to reduce the impact of the constraints of traffic conditions and pouring speed. Flexible dispatching intervals could effectively save trucks' waiting time at site and assist in maintaining pouring continuity.

This paper provides strong theoretical support for the application of RFID and GPS in construction management, especially in supply chain management. Despite a significant initial cost of GPS and RFID tags and readers, long term operational costs could be reduced by applying ADC techniques. A detailed cost –benefit analysis is to be discussed in a following study.

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