APPLICATION OF PRODUCTION SCHEDULING TECHNIQUES FOR DISPATCHING READY-MIXED CONCRETE

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ABSTRACT

Nowadays, the ready-mixed concrete (RMC) industry plays an important role in construction projects, since it has become one of the mechanisms in construction works and it has become more widely used than in the past. Increasing efficiency is focused on in order to be competitive in business. Therefore, this study aims to increase efficiency of the delivery management system by using the modeling of production planning and management of daily scheduling and dispatching of ready-mixed concrete trucks in order to solve the bottleneck problems of production, which are consequently affecting the RMC delivery process .In fact, the capacity of ready-mixed concrete machines seems to be a limitation, since concrete can only be mixed and then delivered in batches, one vehicle at a time. Earliest Due Date (EDD) and First-Come, First-Served (FCFS) are two techniques of priority rules used for RMC scheduling in providing more precision and accuracy of related inputs which can be used in order improve efficiency of the entire RMC process. In the model, factors affecting the RMC delivery process, such as distances, travel speed and travel times are determined by using GIS–Geographic Information Systems software (ArcGIS). The mapping data is also input into the construction site data, which then builds a model based on priority rules to determine the production and dispatching schedule. Preliminary results from the model indicated that delivery delays can be reduced, in addition to improving daily scheduling and reducing planning time. Moreover, the Single Machine-Multiple Sites model was applied to a concrete truck freight management company that had only one manufacturing machine and it had to deliver to several construction sites in various urban areas. By improving efficiency, by optimizing delivery times and by reducing the cost of waiting time at various sites, this PDRMC model could cut operating costs and increase the company's revenue because there will be time for more orders.

Keywords: Come-First Serve; Dispatching; Earliest Due Date; First Ready-mixed Concrete; Schedule

1. INTRODUCTION

Transportation management planning is regarded as the key for handling any activity in the ready-mixed concrete (RMC) industry, because an efficient post-production delivery process could positively affect company incomes by increasing customer orders. Therefore, to improve efficiency of the post-production process, planning and scheduling in RMC delivery should be precise, as well as flexible, responding to various situations, such as changing of customer orders. Often customer orders are urgent and changeable due to labor and construction

conditions. Therefore, delivery precision and flexibility could potentially boost the competitive capability and competitive advantage in the RMC industry. Bottleneck problems in trucks dispatched during the planning process often occur at the stage of RMC mixing because of capacity limitation incurred by availability of only one machine at a time. This generates waiting time for delivery truck in queues. Indeed, RMC mixing and dispatching are two interactive processes which should be linked to one another in the construction sequence.

RMC scheduling problems have been researched quite often in the past. For example, Feng et al. (2004) employed combined simulation and genetic algorithms (GA) in the development of a scheduling model for dispatching RMC trucks for the minimum waiting time at a construction site. Lu (2002) employed similar techniques to integrate a principle of logistics planning through a computer system to produce a HKCONSIM, which is a "simulation platform for planning and optimizing concrete plant operations in Hong Kong." Scheduling for dispatching ready-mixed concrete trucks from a concrete production plant with a one-plant-multisite RMC production system was studied in Hong Kong to analyze effectively the maximum gain from the cost spent on production.

In Thailand, an experienced ordering staff is a delivery planning man, who manually assigns dispatch schedules, based on conditions of minimum truck numbers and maximum orders. The Ready-Mix process, as a bottleneck occurs during the production planning stages and it is often not linked with truck dispatching when delivery of manually RMC is scheduled directly by ordering staff. Indeed, during the RMC dispatch scheduling and delivery planning, ordering staff demand an instant, interactive truck-dispatching plan, operating under existing truck allocation information in order to optimize effectiveness of truck numbers used in RMC delivery planning on time. A combination between production and truck dispatch schedules is therefore essential for increasing RMC plant operating capacity, which would allow a machine to produce concrete for one truck, each time. This might cause time postponement of truck dispatch plans.

Thus, this study aimed to investigate and develop a model for production scheduling and ready-mixed concrete truck dispatching to assist in making decisions on advanced planning among dispatch planning staff members to increase effectiveness, precision, and flexibility. Errors caused by lack of planning expertise could then be reduced; meanwhile, order quantity and company income could also be increased.

2.   EXPERIMENTAL METHOD

2.1.   Production Scheduling

(Baker & Trietsch, 2009), defined production scheduling as a plan or document used to report a quantity of things or activities which would occur within a certain time period as a plan for timing. Production scheduling is generally related to resource allocation and job sequencing for production and service. In general, by production of scheduling types, patterns of machine configurations could be categorized into 4 types as follows (Pinedo, 2009):

1) Single machine scheduling
2) Parallel machine scheduling
3) Flow shop scheduling
4) Job shop scheduling

Moreover, a priority setting technique, known as the Priority Rules Method (RPM), is one of the most popular methods to determine answers in production and other scheduling problems, both in terms of time and cost. The priority rules method uses empirical principles to clarify the concept.

Therefore, production scheduling methods, associated with work sequencing techniques, were used to solve problems as well as to increase efficiency in a plant. In single-machine scheduling, Budsaba (2011) solved late production problems of the hat industry by using the priority setting technique (Priority Rule) from 3 techniques: (1) First-Come, First-Served (FCFS) Scheduling; (2) Earliest due date (EDD); and (3) Longest processing time (LPT). The results indicated that the EDD schedule could reduce the number of delayed jobs, thus reducing tardiness and obtaining optimal results. In addition, Pintaruk (2010), applied similar techniques to solving time-consuming problems for production plan management and delay in work from job sequencing of a chemical product in a manufacturing factory by means of using principles of priority rules, in many ways, utilized for job sequence programming. The results illustrated that reduction of delayed product delivery and overtime hours of working could lead to more productivity.

2.2.   Application of Production Scheduling and Ready-mixed Concrete Truck Dispatching

In terms of Ready-Mixed Concrete (RMC) production scheduling problems, a relationship between production and transportation was examined by using mathematical approaches associated with a heuristic technique for improving effective work plans (Yan et al., 2008). They presented a model integrating production scheduling and truck dispatching for RMC by using a branch-and-bound algorithm to select input data for the planning program CPLEX9.0, the result being related to reducing data processing time. Moreover, the Bee Colony Optimization (BCO) algorithm was developed in production sequencing to obtain an optimum truck dispatch schedule for minimizing total waiting time in a study by Srichandum and Rujirayanyong (2010). Three techniques, including BCO, Genetic Algorithm (GA) and Tabu search (TS), were examined for comparison purposes, resulting in the fact that the BCO technique was more effective and less time-consuming in calculation. The Genetic Algorithm (GA) and Simulation Technique were developed in scheduling of dispatching RMC trucks by Sirisuwon (2009). According to this research, it demonstrated that in scheduling for RMC truck dispatching, production conditions and stages in the working process should be taken into account, since many trucks could not acquire the RMC at the same time from one machine.

2.3.   Model Development

Production scheduling could be regarded as a requirement in solving scheduling problems of RMC truck dispatching, because RMC mixing seems to be a bottleneck in the entire process. Therefore, in this study, the model of production scheduling and truck dispatching was developed and is known as Production and Dispatching for Ready-Mixed Concrete (PDRMC). Earliest Due Date (EDD) and the First-Come, First-Served (FCFS) are two of the Priority Rules techniques used in the RMC process scheduling algorithm as one of the solution techniques in job sequencing of the RMC orders in order to determine total waiting time of the RMC trucks, as shown in Equations 1 and 2 below.

$$\text{Total Tardiness} = \sum_{i=1}^{n} T_i \tag{1}$$

$$T_i = d_i - d_i' \tag{2}$$

where T_i means tardiness i; d_i means a due date i; and d_i' means a new due date i.

The RMC Cycle is a set of operating RMC steps, from start to finish. By adopting from Yan et al. (2008), the RMC Cycle has added one more step, i.e. a preparation step used in operating the RMC process because the concrete preparation step could affect the preparation conditions and situations in the plant site. As a result, there are 5 steps in the RMC Cycle, including concrete mixing, concrete preparation, truck travelling, concrete placing, and truck returning.

2.3.1. Model structure

Figure 1 depicts flow diagram of PDRMC Model comprising of 2 key sections of Priority Rules and Truck Management as detailed in the following chart:
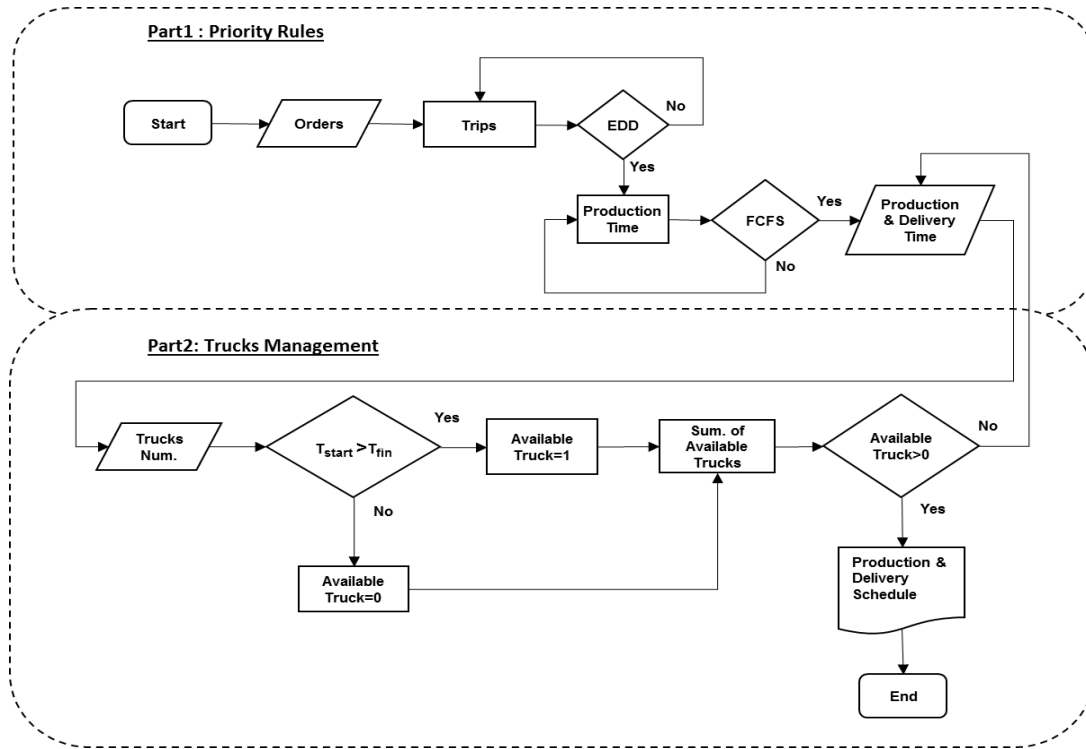

Figure 1 Flow diagram of PDRMC model

- Part 1: *Order Priority Section*: Priority Rules are algorithms used for job sequencing of purchase orders, which generally contain places of delivery, product types, quantity demanded, job types, and requirements related to the number of days and time. By using the distance between each truck, priority rules associated with the just-in-time delivery concept are employed, using job sequencing through the selection criteria of earliest due date (EDD). Once order ranking was carried out, the production starting cycle time of each order will then be calculated using the first-come, first-served (FCFS) priority rules. Production and truck dispatching schedules are outcomes from this section and will be used as input in later section.

- Part 2: *Truck Management Section*: The production schedule will be verified by using the number of available trucks ready for use. If the number of trucks that are available equal more than zero in the factory, it will be considered that production time in that cycle can proceed by job criteria of the previous cycle with startup time (T_{start}) rather than finish time (T_{fin}).

2.3.2. Input data for the model

In the PDRMC model, 5 key inputs including travel time, concrete pouring, concrete volume order, truck capacity and due date and time are described as follows:

- Travel time is used to determine the optimal route from the Geographic Information System Software, ArcGIS, based on road network distance and truck average speed. Truck average speeds for different road types were surveyed by using a database from GPS tracking. This responds to road characteristics and corresponding types of roads, resulting in network-based travel time, as shown in Figure 2a. are Khon Kaen City and its metropolitan area is defined as the study area in this research covering around 228

km^2 and it is divided into 32 zones (See Figure 2b).

- Concrete pouring time was defined as the time used for pouring all concrete in one cycle performed by information agents, according to the observation and experiences of delivery staff.
- Concrete volume order was the information from customers and it will be used to estimate the total number of transport cycles.
- Truck capacity is used a constant number of 6 cubic meters per each vehicle for a standard size of truck capacity. This number is the most industries to be used for calculating a number of transport cycles.
- Due date and time is one of important data used as a condition for considering job sequencing. It is used as starting time data to calculate in a cycle of ready mixed concrete truck dispatching.
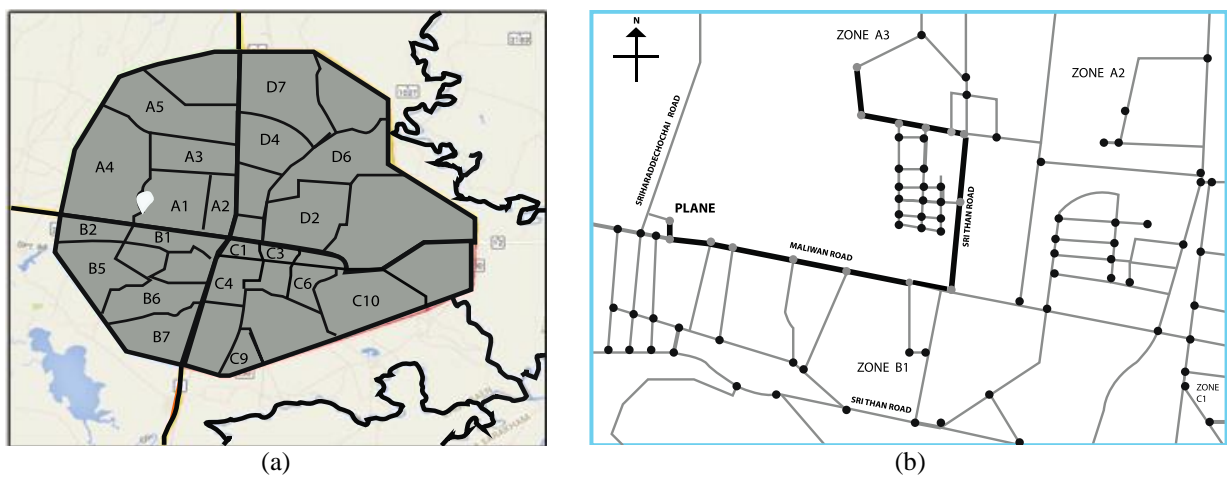

(a)   (b)

Figure 2 (a) Analyzing the suitable route by using ArcGIS; (b) Transportation areas in the model

3. RESULTS

The model of production scheduling and RMC truck dispatching (Production and Dispatching for RMC, PDRMC) employed a useful tool in data processing, and displaying results was developed by using Macro and Visual Basic for Applications in Microsoft Excel.

3.1. Data Input Methods

PDRMC model is comprised of two main sections, including RMC Planning and Report-Data. In RMC planning the priority rules are used for job scheduling and the Report Data Section provides results of production and dispatching for the RMC schedule

Table 1 Classification of data

Basic input data	Analyzed data
1. Concrete volume	
2. Truck capacity	
3. Concrete mixing time	1. Concrete pouring time
4. Due date time	2. Travel time
5. Place of delivery	
6. Job descriptions	

Table 1 shows the details of input data used in the PDRMC as detailed in Section 2.3.2. Once basic input data is set, concrete pouring time and travel time will then be calculated in terms of analyzed data for further use in the model.

3.2. Displaying Results

The model results will be displayed as shown in Figure 3, consisting of two parts, including delivery job sequencing and a graph of truck numbers used.
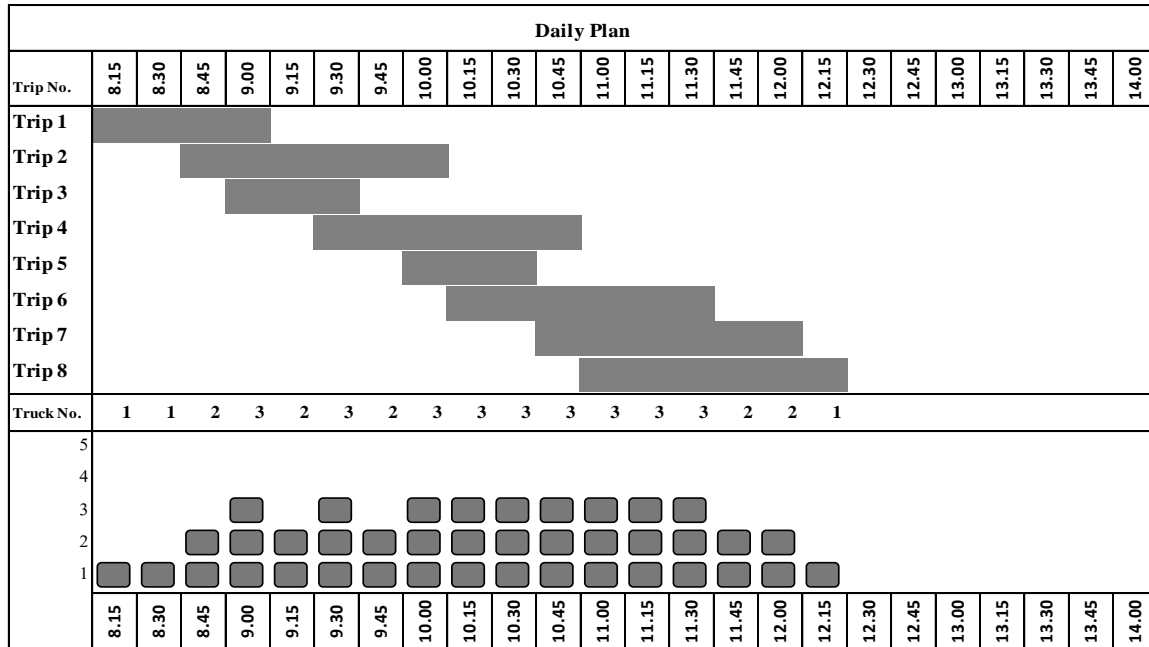

Figure 3 Result of simulating truck status

Delivery job sequencing for each cycle is presented in a Gantt chart, consisting of a place name for product delivery, carrying capacity per cycle, startup time and truck return time to the plant. The bar chart shows the number of trucks needed for use, depending on time intervals. The truck number is calculated instantly when job sequences are modified. As a result, the displaying methods of the PDRMC model supported providing truck numbers instantly with changed plans or other input data, which could greatly help during the planning stage for ordering staff.

4.   DISCUSSION

A sensitivity analysis is a technique used to determine how different values of an independent variable will impact a particular dependent variable under a given set of assumptions (Root, 2003). Sensitivity analysis is then used to examine stability of the PDRMC model. The relationship between fleet size and delay time were explored and results are shown in Figure 4. The delay time will decrease with the increasing of fleet size.
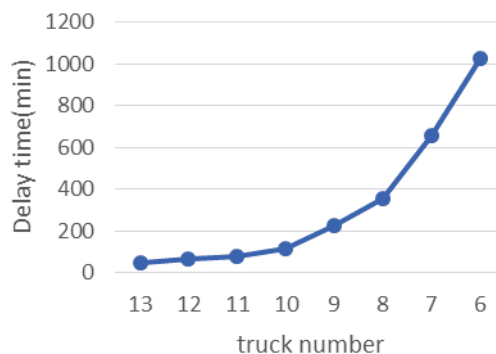
Figure 4 Sensitivity analysis of fleet size

5. CONCLUSION

This research presented the PDRMC model to assist in ordering staff decisionmaking in creating a schedule for dispatching ready-mixed concrete trucks in order to solve problems due to inconvenience and lack of efficiency. According to truck dispatch officers' planning for the PDRMC model under the concept that took constraints of production process into account, it was illustrated that the model could be used to calculate total tardiness of truck dispatch plans and a right number of trucks. The obtained result could be used for more effective job sequencing than just by making plans from truck dispatch officers based on minimizing total tardiness. In addition, the model could be used as a tool for making a decision on receiving more purchase orders in remaining periods of time because of displaying methods, which could present the overall plan clearly. It was considered a tool for analysis and it helped in administering the allocation of a limited number of trucks effectively. Therefore, this model should be used to develop and be applied to the ready-mixed concrete industry.

Future works may include a further sensitivity analysis of the concrete demand and the delay time to provide more details for verification and assessment of the PDRMC Model. Moreover, comparison of scheduling will be performed from both the PDRMC Model and manual efforts.

6. ACKNOWLEDGEMENT

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