IMPLEMENTING KANBAN CONCEPT IN PRODUCTION PLANNING AND CONTROL FOR A DOMESTIC PRECAST MANUFACTURING PLANT

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DECLARATION

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

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NOMENCLATURE

PPC	Production Planning and Control
DES	Discrete event simulation
WIP	Work-in-process
MRP	Material Requirements Planning
QC	Quality Checking

ABSTRAK

Perancangan pengeluaran dan kawalan (PPC) adalah faktor utama bagi kejayaan dalam produksi. Kajian ini bertujuan untuk mengenal pasti perancangan dan kawalan kaedah semasa dalam produksi di Malaysia kilang berasaskan tempatan yang dipanggil sebagai MDC Precast Industries Sdn. Bhd. Mesin digunakan, beberapa operator dan masa kitaran bagi setiap proses dikumpulkan untuk menyiasat perancangan semasa dan kawalan dalam produksi. Kemudian, carta Pareto dipetakan untuk mengenalpasti punca kepada prestasi mesin yang rendah. Model produksi semasa dan model produksi Kanban adalah simulasi menggunakan perisian SimEvents. Konsep Kanban dilaksanakan dalam bahan mentah pengisian semula yang sangkar keluli dan cangkuk. Penjadualan baru dicadangkan untuk mengelakkan melahu mesin. Hasilnya, penggunaan mesin telah meningkat daripada 56.4% kepada 80% dan tiada penungguan masa untuk pembekal sedia campuran. Oleh itu, penjadualan yang betul dan penggunaan Kanban alat dapat meningkatkan kecekapan pengeluaran.

ABSTRACT

Production planning and control (PPC) are key factor for a success in production. This study aims to identify the current planning and control methods in production line in Malaysia local based manufacturing plant which is called as MDC Precast Industries Sdn. Bhd. The machine used, number of operators needed and cycle time for each process are collected in order to investigate the current planning and controls in production line. Then, pareto chart is mapped to identify the root cause of low performance of machine. Current production model and Kanban production model are simulated using SimEvents software. Kanban concept is implemented in replenishment raw material which is steel cage and hook. New scheduling is suggested to avoid the machine idling. As a result, machine utilization was increased from 56.4% to 80% and no waiting time for the ready-mix supplier. Therefore, with proper scheduling and applying Kanban tool will increase the efficiency of the production.

Implementing Kanban Concept in Production Planning and Control for A Domestic Precast Manufacturing Plant

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ABSTRACT

Production planning and control (PPC) are key factor for a success in production. This study aims to identify the current planning and control methods in production line in Malaysia local based manufacturing plant which is called as MDC Precast Industries Sdn. Bhd. The machine used, number of operators needed and cycle time for each process are collected in order to investigate the current planning and controls in production line. Then, pareto chart is mapped to identify the root cause of low performance of machine. Current production model and Kanban production model are simulated using SimEvents software. Kanban concept is implemented in replenishment raw material which is steel cage and hook. New scheduling is suggested to avoid the machine idling. As a result, machine utilization was increased from 56.4% to 80% and no waiting time for the ready-mix supplier. Therefore, with proper scheduling and applying Kanban tool will increase the efficiency of the production.

Keywords: planning and control, Kanban concept, discrete-event simulation

I. INTRODUCTION

Most companies especially local based manufacturing company in Malaysia always faced in improving productivity and production problem. By solving this scenario, they normally adding more resources such as workers and equipment to achieve the customer demand. Basically, the production issues are always come from production planning and control. In precast production can be divided into two categories according to the difference in production methods, namely flow shop production and fixed location production (Yang, Ma, & Wu, 2016). In this company, precast production line is fixed location production which all tasks of a component are handled in a fixed workstation by the same teams. Yang, Ma, & Wu (2016) have been declared that the limitation of fixed location production when compared to flow shop production. The production capacity and resource utilization rate will be lower due to the limitation of floor space. The resource planning problem in precast concrete using generic algorithm had been mentioned in Khalili & Chua (2014) research. Planning controls is to fulfil the task to plan and control production processes in terms of quality, schedule and capacity. Heesa & Reinharta (2015) discussed about the reconfigurable system which is including planning, scheduling and optimization of the whole company. This could help in long terms scheduling and direction of the organizational company. There is another approach that suggested by Cichosa & Auricha (2016) which is involving production program planning using algorithm. In order to move forward to the globalised level, Artificial Intelligence Planner is developed by Benjaorana & Dawoodb (2006) where the system is semi-automated. It is a huge leaps to achieve the Industry 4.0. The aims of scheduling is to optimize the workload of the task and reduce the completion time and latency time. Planning process have been categorize as threes area which is long-range plans, intermediate-range plan and last is short-range plans which job scheduling is one of the issues. Liu, Xu, Zhang, & Wan (2017) use generic algorithm to schedule multi-task scheduling with each subtask which is with time contraint and without time contraints.

Discrete event simulation (DES) can be used in many areas. Modelling helps in enhancing the performance of the systems. In the studies of modelling maintenance system, the simulation had been break down the cases in time-based preventive maintenance and condition based maintenance with periodic inspections (Tiwari & Alrabghi, 2016). This could help to reflect the real-time performance when such cases are occurred. Process flow chart should be drawn when develop the simulation model. Optimisation can be done in simulation with using optimisation algorithm while Ünlüyurt & Tunçer (2016) use mathematical models to do simulation. Discrete-event simulation model help in planning. Babashov, et al. (2017) suggested that by considering resources and sequential steps of the process can measure the effect of several resources changes. "What-if?" analysis can be carried out to determine good planning, resources and reducing waiting time and improving workflow by using DES. "What-if" analysis is one of the method to investigate different scenarios where we can evaluate the realistic scenarios. DES models are used to investigate scheduling challenges, waiting time bottleneck, throughput and so on. The performance metric should be set in advanced in order to achieve the target. Before identifying performance metric, factors affecting the performance indicators should be determined. For example, process, structures and outcomes are the factors need to be identified (Radhakrishnan, Duvvuru, & Kamarth, 2014). There have many ways to conduct validation. Validation is done by comparing the model outputs to actual system performance. Ünlüyurt & Tunçer (2016) also use simulation by comparing real data and changing for random data. Validation also can be done in statistical way such as using t-test.

MDC Precast Industries Sdn. Bhd. is a manufacturer which specialized in manufacturing of precast reinforced products which included Box Culvert, U-Shaped Drain, L-Shape Retaining Unit, Reinforced Concrete (RC) Square Pile, Prestressed Beams and Special Designed Precast Reinforced Concrete Products. This manufacturing plant consists of eleven production lines, four batching plants which is provide ready mix and one steel cage preparation warehouse. In this paper, production line number nine which is producing different types of Box Culvert and U-Shaped Drain product is used as case study. The manufacturing flow in this company is shown in Figure 1. The manufacturing flow start with making raw material which is ready-mix and reinforcement steel cage and mould preparation. Then, assembly the steel cage into the mould and then continually with concreting process where mix with ready-mix concrete. Quality checking(QC) need to be done in mould preparation stage and demoulding stage. After concreting process, finishing and curing process are carried out. QC engineer will check if product can be rework when defects occurred. Concrete cube testing is undergo to check whether the product is in good condition and lastly, it will loading and move to the site. In this production line, it is high mix low volume production which produces various type of precast concrete. The products in production line are made to stock and made to order. The type of products in this line are comprises of 300mm series, 450mm series, 600mm series, 750mm series, 900mm series, reinforced concrete parapet, slab cover series and lid series. There have 24 operators in a team which is responsible for the whole process from mould preparation to demoulding process. Some of the operators will be assigned to a specific task while the rest will be assigned to mould cleaning process and mould assembly process.

Mould has to well-prepare in batch as concreting process is carried in batch. Therefore, operators are assigned to prepare the mould needed in batch, then place order for ready mix from batching plant supplier. However, long wait time is occurred as the batching plant need to supply to other production lines. The performance of the production hopper that carry the ready mix is low. Next, operators are not informed to perform a task for product series and as a result they carry out the job randomly. Thence, the mould preparation process take longer time which causing the production hopper is idling. Insufficient raw material sometimes occurred in the production line as result in causing the downstream process will be affected. In order to reduce waiting time for raw material, operators will proceed to another type of product. In this project, the objectives are to identify the current problem of production line and to implement Kanban concept to optimize the raw material. SimEvents software is used to simulated current production and Kanban production model. In short, long wait time from suppliers will cause underutilization of machine which will reduce the performance of the production.

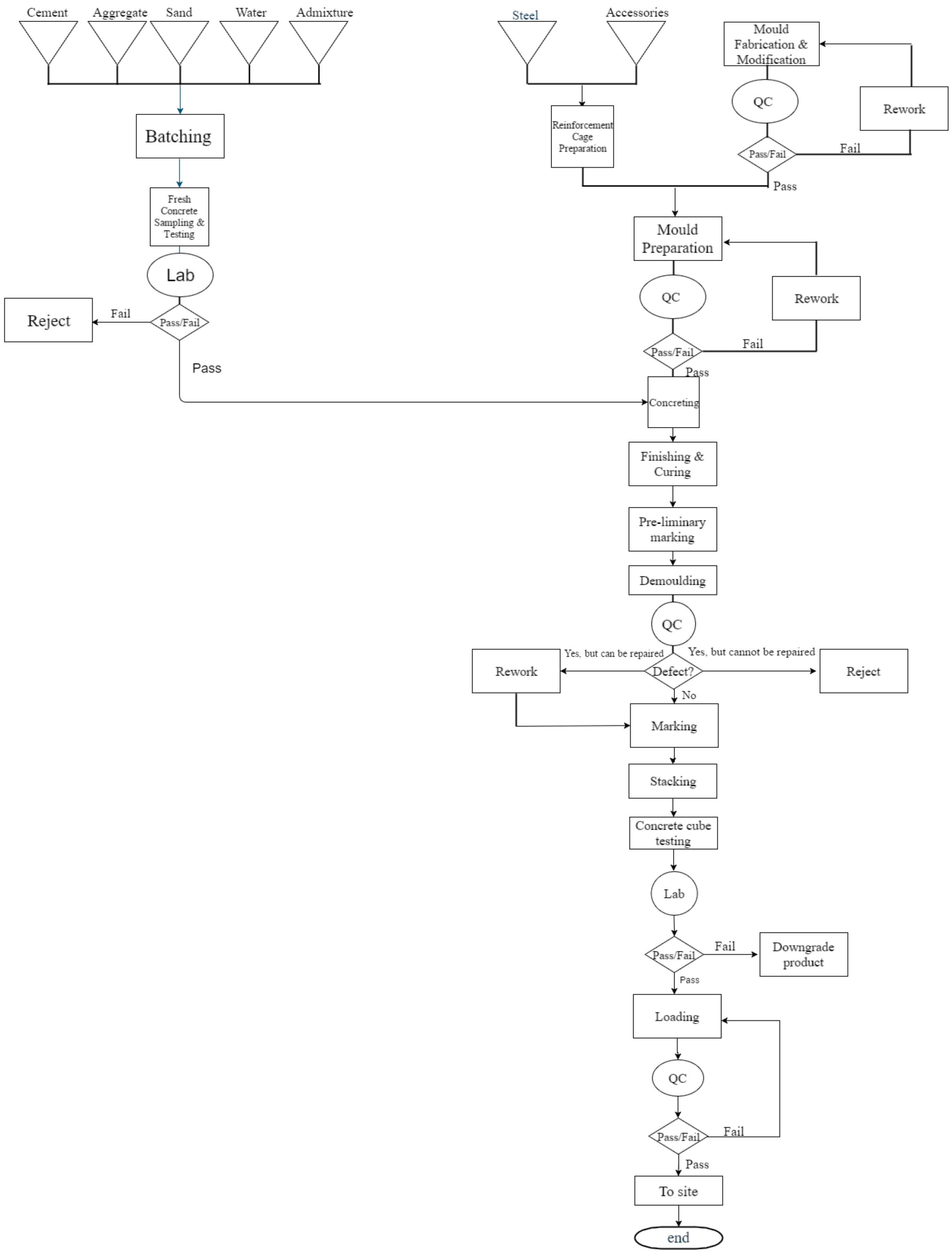

Figure 1 Manufacturing Flow in MDC Precast Industries

II. Methodology

The methodology of the study followed is shown in Figure 2. Data is collected and analysis of data is performed in order to identify problem. After required data is collected, the current simulation model is developed using SimEvents simulation software. Then, the Kanban production model is built in order to improve the performance of the production.

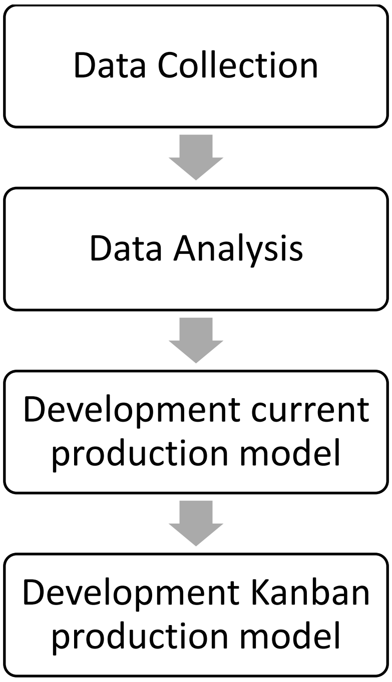

Figure 2 Methodology for study

A. Data collection

MDC Precast Industries company operates for 24 hrs. The current working hours of operators is shown in Table 1. The working time of operators is inconstant which depends on the supervisor. Average working hours per day is about 12 hours 30 mins. Cleaning process until demoulding process is carried out in the working time while there are another five operators will continually carry on demoulding process and some cleaning process until next day morning.

Table 1 Current working time of operators

	Operator
Average working time	8am- 10pm
Number of working days	6 days
Break time	1hrs 30mins
Number of shift	1

For this study, product group of 900mm series, 750mm series and 600mm series are selected to determine the average cycle time. Average daily output data was collected over a period of 3 months for December 2016, January 2017 and February 2017 as shown in Figure 3. Figure 3 illustrates the highest average daily output amongst the product series is 900mm series and following by 600mm series and lastly is 750mm series. This is because the demand of 900mm series is highest compared to others.

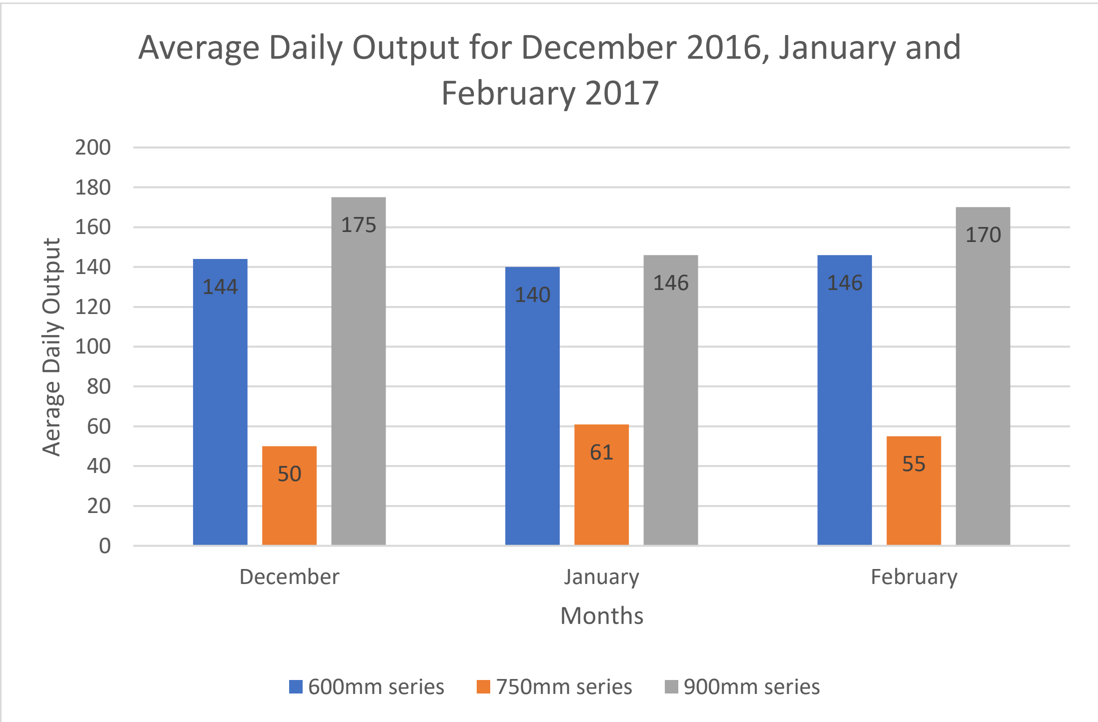

Figure 3 Average Daily Output for December 2016, January and February 2017

Time study method is used to identify the standard time to conducting a work. Data was collected manually using stopwatch randomly. The average cycle time of each steps in production line was taken as shown in Table 2. The time taken for each task element is vary therefore work sampling method is used to improve the accuracy of the data. Based on the confidence interval of 90% and using Student t-distribution, so the number of observation can be determined.

Table 2 Cycle time of each process

Work elements	Cycle time (second)
Cleaning	100
Assembled Mould (front door)	57.13
Assembled Mould (end door)	127
Spray oil	1.2
Insert steel cage	13.5
Insert hollow bar	23.16
Concreting	650 per batch
Compacting	255.7
Finishing	44.51
Insert hook	36.8
Curing	21600
Demoulding	131.23

B. Data analysis

From the data collection in Table 2, the bottleneck process is found which is curing process. The longest cycle time which is six hours. It has accumulated many products in one time and next process is starving. In the production line, there is only one machine called as production hopper used in concreting process. The functionality is to transfer the ready mix to the mould and it is handled by operator.

Concreting process is a pacemaker process. This is because it allowing to pull material to it. Based on the ideal case, the concreting process for 900mm series and 750mm series can be run for second cast in production line. However, in real situation, the production hopper machine is not fully utilized. The performance of the production hopper is low. Otherwise, production hopper play an important role to improve productivity. There are some factors that observed in the production line that causing the production hopper is low efficient. Pareto Chart is plotted to identify which is the most occurrence as shown in Figure 4.

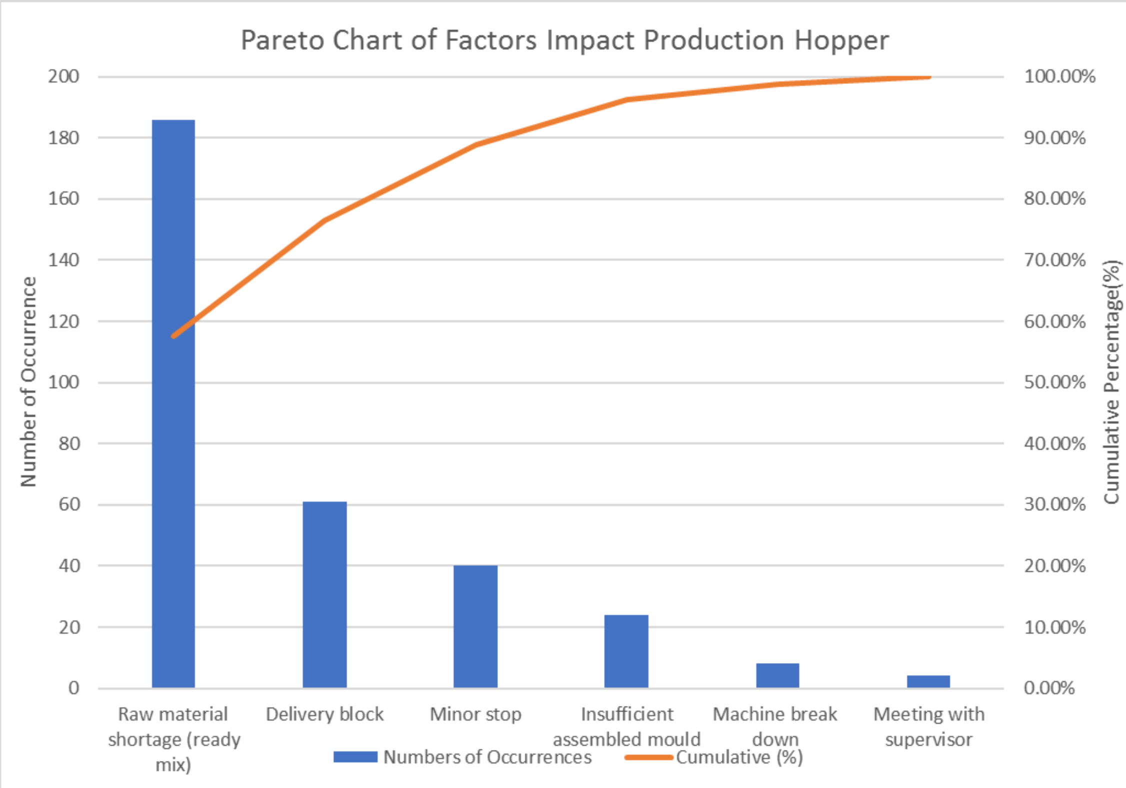

Figure 4 Pareto Chart of Factors Impact Production Hopper

According to the Pareto Chart in Figure 4, the factor that affect the most to the performance of the production hopper is the due to raw material shortage and following by delivery block. Production hopper machine are always waiting for the ready mix from the batching plant. Ready mix is ordered by the operator when it is needed. The time taken for arriving raw material is also inconsistent. When delivering the ready mix, the production hopper always being blocked by the gantry machine. This is due to the limitation of the structure. Minor stop such as production hopper jam for a while and operator chit-chatting is ranked as third while insufficient assembled mould means that previous process is not well-prepared and causing the concreting process is delayed. Production hopper break down ranked at fifth and the rank at last is factor of sudden meeting of operator with supervisor.

C. Development current production model

Simulation is a computer model that creating and analyzing an operation of a real system. Once all the required data is identified, simulation model is built using SimEvents simulation software to represent the process of the production line. In order to simulate the production model, the process flow chart is shown in Figure 5. The process is started with mould creation and then following by each process and lastly is inserting hook process. Production operation parameters such as cycle time of each task elements, number of operators involved and raw material replenishment are involved to build the simulation model.

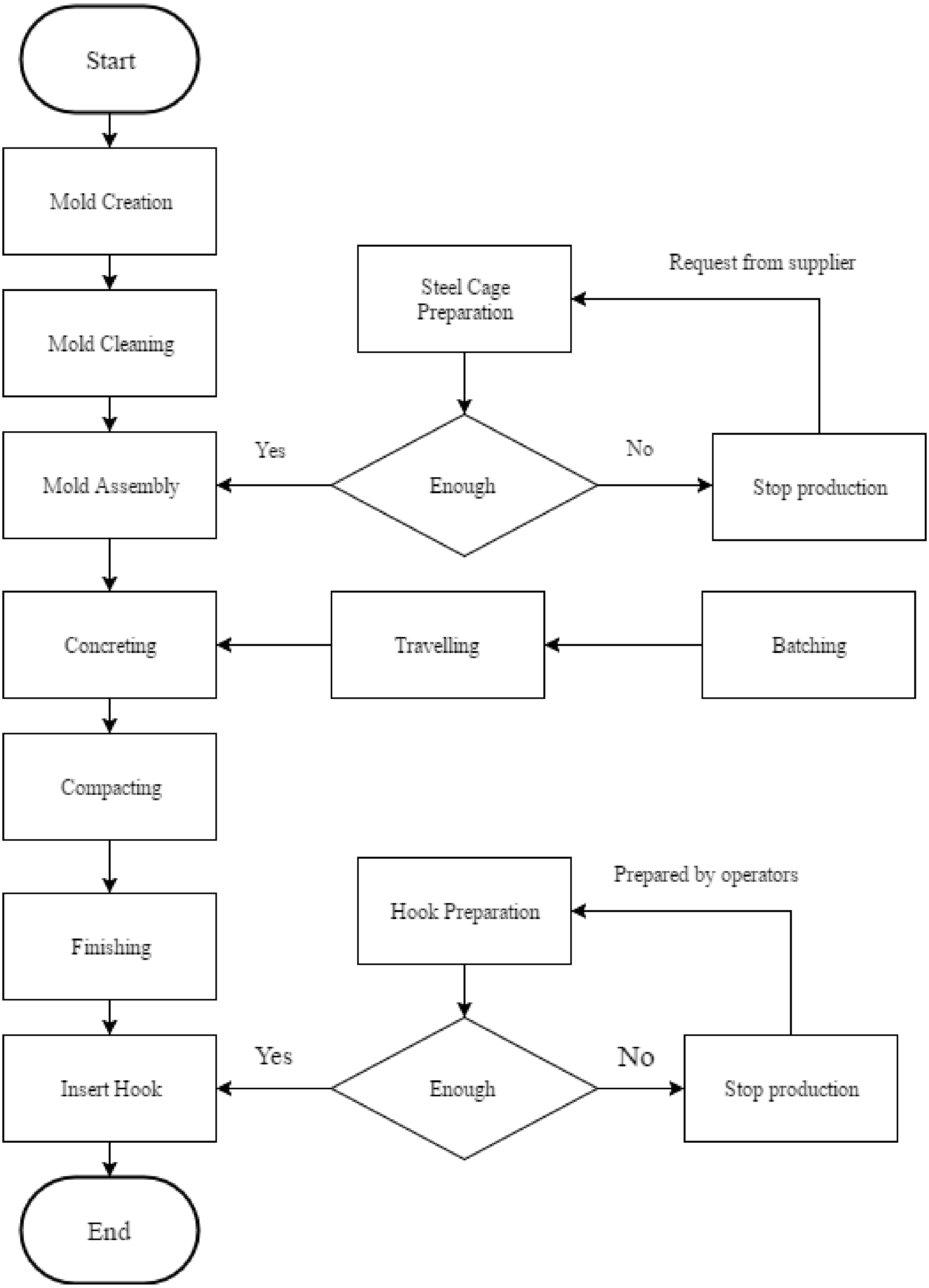

Figure 5 Process Flow for Current Production Model

The simulation model was built based on the fundamental of production system as shown in Figure 6.

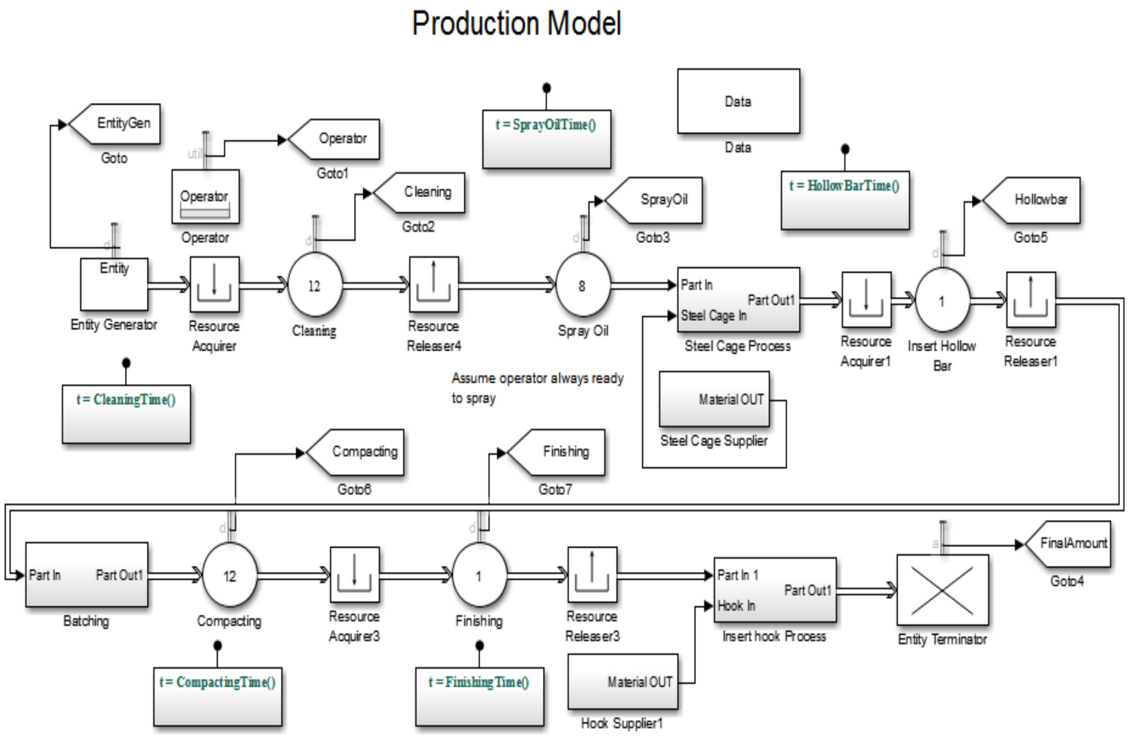

Figure 6 Simulation Model in Production

Several assumptions were made to simplify the simulation process:

- Each group product has similar cycle time.
- Consider the raw material supplied is similar.
- The number of operators are set as 24 persons.
- Assume operator always ready to spray oil process.

In Figure 6 shows the all the steps of produce precast concrete. Curing process is not included in the production due to highest cycle time which is six hours. Mould is first as an entity generator and following with supplying resources which is operators to perform the task. Each process is follows a Gaussian distribution. In simulation model, each of the process had been assigned operators as resources to complete the task except spraying oil and compacting process. This is because consider the subpart is produced by batch by an operator. In simulation model, server is used as each process and the capacity is set based on the ready mix supplier in one batch. Table 3 shows different group products will produce different number of output in batching process. For 600mm series, 17 pieces can be produced in one batch because of ready mix supplier while 750mm series is 15 pieces and 900mm series is 12 pieces. Therefore, in production model the server will be changed when run for different group product series.

Table 3 Number of output produced per batch in different group products

	600 mm series	750mm series	900mm series
Number of output produced per batch	17	15	12

For steel cage supplier model section as shown in Figure 7, there are two gates to indicate stop and run of the production system. When raw material is insufficient which set as less than 10 per assumed, the production will stop and the supplier from raw material will get inform. The capacity for delivery the steel cage to the workplace is set as 20 as based on the current production system. This situation same goes to another raw material which is hook as shown in Figure 8.

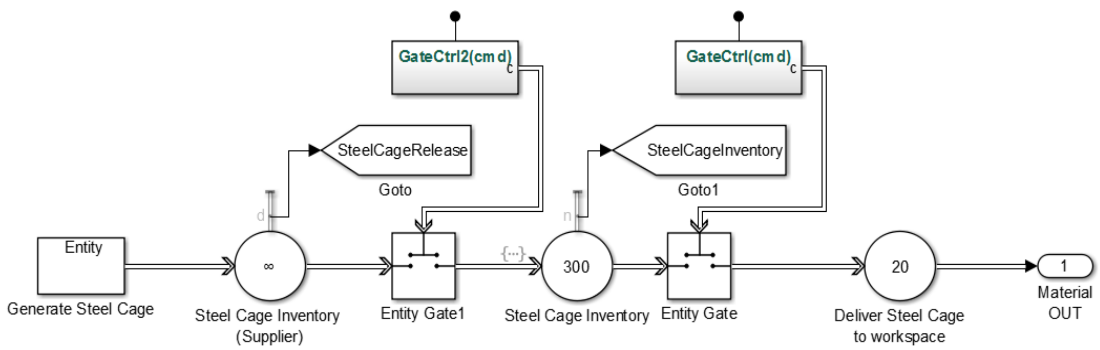

Figure 7 Steel Cage Supplier Model

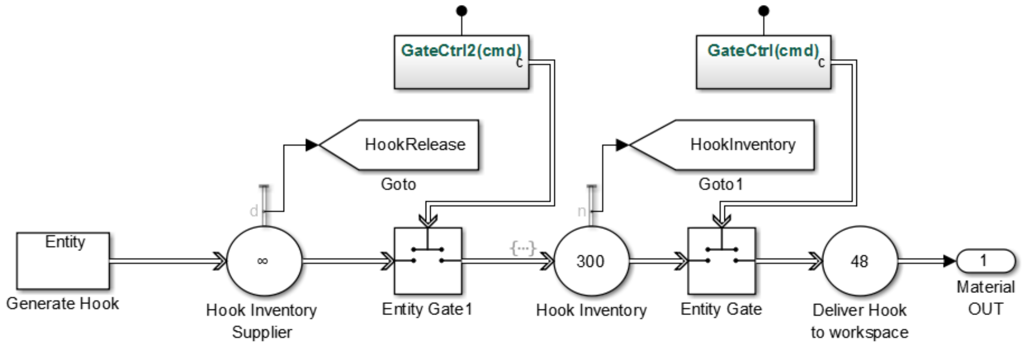

Figure 8 Hook Supplier Model

For batching session, buffer is added to indicate that the production lead time of preparing the ready mix as shown in Figure 9. The server for concreting process is set as 12 because 12 pieces will be produced in one batch.

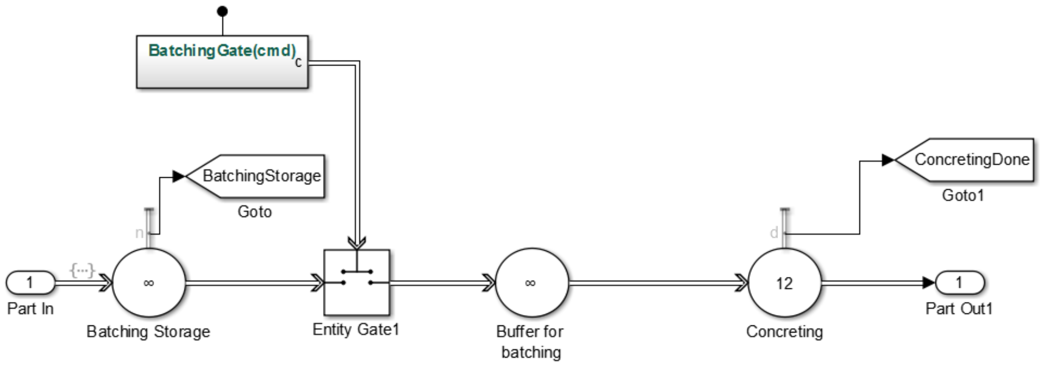

Figure 9 Batching Process Model

D. Verification and Validation

The current production model need to be verified so that it can accurately reflect the real system model. The simulation is replicated to get 10 set of daily output of group product series and compare with the real historical data as shown in Table 4. The confidence interval used is 95% for difference with α = 0.05 and the lower and upper interval is calculated as:

$$\text{Lower and upper interval} = \bar{x}_{s-}\ \bar{x}_r \pm t_{n-1,\alpha/2}\sqrt{\frac{s_s^2+s_r^2}{n}}$$

$\bar{x}_s$ = Mean of simulation output data

$\bar{x}_r$ = Mean of real system output data

S_s = Standard deviation of simulation output data

S_r = Standard deviation of real system output data

$t_{n-1,\alpha/2}$ = Value from Student's t-distribution (in this case is 2.262)

The t-value is calculated as:

$$t = \frac{\sum D/N}{\sqrt{\frac{\sum D^2 - (\frac{(\sum D)^2}{N})}{(N-1)(N)}}}$$

D = Difference between real data and simulation data

N = Number of data

Two hypotheses were made in two-tailed t-test.

H_0: model output = real output

H_1: model output ≠ real output

Table 4 Paired-t confidence interval for real and simulation system

No	**Simulation Data (Daily Output)**	**Real Data (Daily Output)**	**Difference ($O_s - O_r$)**	**Difference^2 ($O_s - O_r$)^2**
1	99	96	3	9
2	87	94	-7	49
3	75	96	-21	441
4	110	93	17	289
5	96	90	6	36
6	50	51	-1	1
7	45	40	5	25
8	96	92	4	16
9	48	72	-24	576
10	60	84	-24	576
Mean	76.6	80.8	-4.2	201.8
Standard deviation	24.2	20.1	14.3	201.8

Variance		585.64	404.01	204.49	40723.24
		95% confidence interval for difference			
Lower interval	Upper interval	Calculated t-value		t-value from table	
-26.7	18.3	-0.928		2.26	

By using two-sided test, the calculated t-value is smaller than the t-value obtained from the t-distribution table (the negative sign is ignored as it represents as direction) and the difference between the real data and simulation data is within the upper and lower interval, and the calculated t-value which is 0.928 is lower than 2.26 thus the null hypothesis is accepted. The specifications and parameters in the simulation system is similar which can reflect to real system.

E. Development Kanban production model

In order to avoid stop production while facing insufficient raw material, Kanban method is suggested to implement in the process. Kanban system is helpful as it provides direct control on the amount of work-in-process between cell. The number of Kanban cards is computed as follows:

$$Number\ of\ kanbans = \frac{Demand\ during\ lead\ time + safety\ stock}{Size\ of\ container}$$

In this study, Kanban is suggested for replenishment of steel cages of each types of products. For the product 900mm series, 750mm series and 600mm series, the number of Kanban are calculated as shown in Table 5.

Table 5 Number of Kanban needed for each types of steel cages

Types of steel cage	900mm series	750mm series	600mm series
Daily demands	200	80	200
Container size	100	50	100