Production Sequence Using Simulation Techniques: Case Study of Mineral Production Plants for Dairy Cow

Pramot Thongman and Nara Samattapapong
School of Industrial Engineering, Institute of Engineering,
Suranaree University of Technology
Nakhon Ratchasima, Thailand, 30000
pramote.thongman@gmail.com, nara@sut.ac.th
Vorasiri de Cadenet
School of Environmental Engineering, Institute of Engineering,
Suranaree University of Technology
Nakhon Ratchasima, Thailand, 30000
vorasiri@sut.ac.th

Abstract

The objective of this research was to apply the Flexsim® simulation program to find the most suitable production sequence for a case study factory. The researchers experimented and found the most appropriate production sequence by entering 25 orders, the total production amount of 520 tons into the simulation model and experimenting with the production order of Earliest Due Date (EDD), Longest Processing Time (LPT) and First Come First Serve (FCFS) by experimenting with 30 replications in each format. Based on the analysis of the experimental results, it was found that the EDD production sequence has the least makespan time of 164.170 hours and without a tardy job. Whiles the LPT production sequence has a makespan time of 166.545 hours and the number of tardy jobs is 74 tons. The FCFS production sequence has a makespan time of 163.641 hours and the number of tardy jobs is 59 tons. From the simulation results, considering the smallest makespan time and the least tardy job, the EDD production sequence is most suitable because the makespan time is 164.170 hours which is the second smallest production time and without a tardy job which is the least amount of delay from all 3 forms of the production sequence.

Keywords: Simulation, Sequence, Continuous Manufacturing

1. Introduction

The United States Department of Agriculture estimated that the amount of global raw milk product of 2019 totaled about 51 million tons, which is an increase of 2.0 % from the previous year. The main producers of the global dairy industry include the EU (30.44%), the US (19.50%), India (15.59%), China (5.77%), Russia (6.21%), and Brazil (4.51%). In terms of marketing, in 2019 the US had forecasted that the exporting marketing for dairy products (four main types: skim milk powder, whey powder, cheese, and butter) of these main producers would be expanded. Additionally, the percentage of skimmed milk powder would be raised by 0.73% (New Zealand 12%), skim milk powder increased by 7.29% (New Zealand 5.77%), cheese increased by 2.29% (EU 1.2 percent, New Zealand 9 %), and butter increased by 0.45% (New Zealand 0.99%). For the situation of the dairy industry of Thailand in 2019, the department of livestock development estimated the amount of raw milk at about 1.3 million tons, worth 800 million USD. As for the quantity of raw milk that was agreed upon between the farmers and entrepreneurs for the 2019 fiscal year (October 2018 - September 2019) of the Dairy Committee, the amount is 3,413.142 tons per day or approximately 1.25 million tons per year (the annual report in 2019 of Dairy Farming Promotion Organization of Thailand).

The animal feed industry in Thailand is continuously developing in many areas, such as through academic research, import substitution, animal nutrition and feed formulation, improving the process of animal feed production, and improving packaging and transportation become essential. The current status of the animal feed industry is also associated with other manufacturing and service sectors such as industrial crop production, livestock production, the processed food industry, the transportation industry, and the communication industry.

For this reason, the animal feed industry plays an important role to the macro- and micro-economies of the country by increasing a lot of income to all related sectors. In 2017, valuation occurred throughout the animal production chain such as animal feed factories, livestock farming and the aquaculture business. Moreover, processed food from animal and aquatic products for domestic consumption and export increased to 315 billion baht and 875 billion baht, respectively (Kantanaamulkul, 2019)

The case study company is a medium-sized business that produces and sells animal feed (minerals for dairy cows). Formerly, the company had discontinued production because the workstations were separated and relied mainly on production staff. Therefore, it cannot reach the needs of entrepreneurs who want to increase productivity. Currently, the company has already improved all basic structures and production processes including the usage of continuous production with modern machinery and a tubular chain conveyor. One of the biggest problem is the case study factory's production plans since it is designed by their own experiences without any factual or systematic information. This leads to the difficulties in the resource planning and preparation since the actual daily usage of resources is unpredictable. The struggle of the production sequence is the most complicated problem due to its limitations. This problem might not meet the requirements of entrepreneurs who want to broaden productivity to support more orders in the future. Consequently, applying the simulation techniques might conduct a suitable production sequence for this factory case study.

2. Literature Review

The study of production sequencing through simulation techniques (case study of mineral processing plants for dairy), it is imperative to learn and understand the theories of production scheduling and job sequencing, and problem modeling. The following content will discuss the related theories, research and articles as follows.

2.1 Related Theory of Production Sequence

2.1.1 Definition

Production sequence is the process of scheduling the start and end of each job for the available resources in order to perform assigned tasks in different situations (Barkany A. et al., 2019). Moreover, production sequencing means determining the relationship of the workflow to be produced under limited resources such as machines, workers, and material handling for completing the production in a specified timeframe (Lalitaporn, 2010).

2.1.2 Objectives

There are various purposes of production sequence including the highest machinery utilization rate, delivering works on time, or the least shutdown time of the system, etc. The general purpose of scheduling the production can be classified by the following indicators (F Shrouf, J. O.-M et al., 2014).

1) Mean Flow Time
2) Mean Lateness
3) Mean Tardiness
4) Number of Tardy Jobs
5) Makespan
6) Maximum Tardiness

2.1.3 The process

The production schedule is quite a complicated system in terms of dissimilar work orders (different production processes). The person who is responsible for the production sequence has to arrange the production schedule appropriately. In addition, the factory scheduling starts from the factory receiving orders from customers or sales. Each production order shows the number of different parts that need to be manufactured (each order might involve more than one job). In order to reach the planned schedule, all pieces or parts must go through each manufacturing process at the specified time based on the order. next, the step of doing the production sequence is mentioned as follows;

1) Job assignment is a determination which jobs will be performed by which production units.
2) Evaluate workload is the evaluation of the workload after determining which departments need to use it in the production and then verify the capacity of that agency whether it is able to perform the specified task.
3) Sequencing is the sequence of production by reducing the accumulation of work between departments. This means that the average job number will be reduced awaiting in the queue. If the amplitude of all the operating times is constant, it means that the average working time and waiting lists can be reduced.

2.2 Related theory of simulation

2.2.1 Definition

Simulation is one of the methods used in the process for solving the problems in various areas that have gained attention and alertness in the widespread fields as a result of the advancement in computer technology [6]

2.2.2 Types

Types of simulation can be classified by distinctive systems of work and there are also unique characteristics of the model which can be classified by special features as follows;

1) physical model
2) analog models
3) Management game
4) computer modeling
5) mathematical model

2.2.3 Procedures

The current simulation (problem modeling) is often used for the complex problems. It requires a computer for calculating information leading to analysis of solutions. There are following procedures;

1) Define the problem and define the work system.
2) Modeling
3) Data preparation
4) Processing of models
5) Testing validity
6) Experimental design
7) Planning of model implementation
8) Conducting experiments
9) Interpretation of experimental results
10) Applications
11) Documentation of usage

2.2.4 Reasons of usage

The use of problematic simulations instead of real work is due to a number of reasons or necessities.

1) The actual work system cannot stop working.
2) Experimenting with the real work system will be expensive.
3) Experimenting with the real work system will take a lot of time.
4) The model can meet the test results as required.
5) The model can be used for many situations.

3. Research Methods

This study provides the optimal sequence of tasks with grading rules by applying simulation techniques. The researcher has followed these mentioned steps.

3.1 The Factory's Current Situation

This part covers general information, information about the production process, and product information.

3.1.1 General Information

The case study factory is a medium-sized business that operates on the production of minerals for dairy cows. It is located in the Pak Chong district of Nakhon Ratchasima Province. At present, the factory has a continuous production system by controlling the work and regulating through the computer. They work Monday to Friday from 8:00 am to 5:00 pm.

3.1.2 Product Information

The product of the case study factory is mineral supplements for dairy cows of all ages. Currently, the factory produces, sells, and manufactures four formulas.

3.1.3 Information of Production Processes and Production Procedures

The case study factory has all production processes shown in the following diagram:

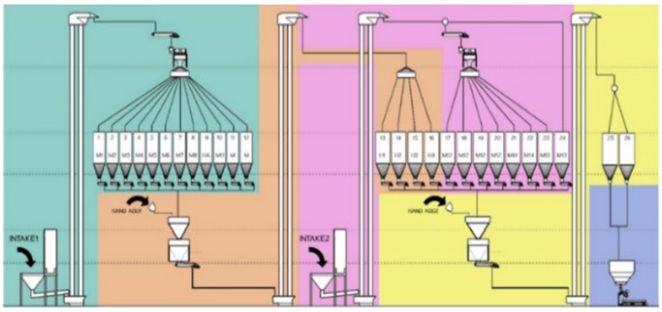


Figure 1. Production processes

The following is from Figure 1, the study of the current situation of the factory. The production process can be divided into different sub-processes, as follows.

1. The importing raw materials process to produce the mineral concentrates: there are 12 types of raw materials which are used to produce mineral concentrates. Concentrates will be transported to mix in the storage tank.
2. The mineral concentrate production process (raw materials to produce minerals): this starts by pulling each raw material from the storage tank and mixing them to become the mineral concentrates based on the defined formula.
3. The importing raw materials for mineral production process: there are four types of raw materials which are transported to mix in the storage tanks.
4. The mineral processing is the mixing all ingredients process based on the defined formula by pulling out one concentrate and other raw materials from the storage tank. The raw materials will be pulled one by one until the quantity has reached the defined formula.
5. The packing process is where the employees will pack minerals into the bags. There are three packing steps: filling the bag, sealing the bag, and arranging them into pallets for delivery to the customers.

3.1.4 Factory Layout Information

From the study of the current situation of the factory, the factory layout is planned as shown in the figure below. The case study factory is divided into four floors; each floor has a working area which is separated to each production process.

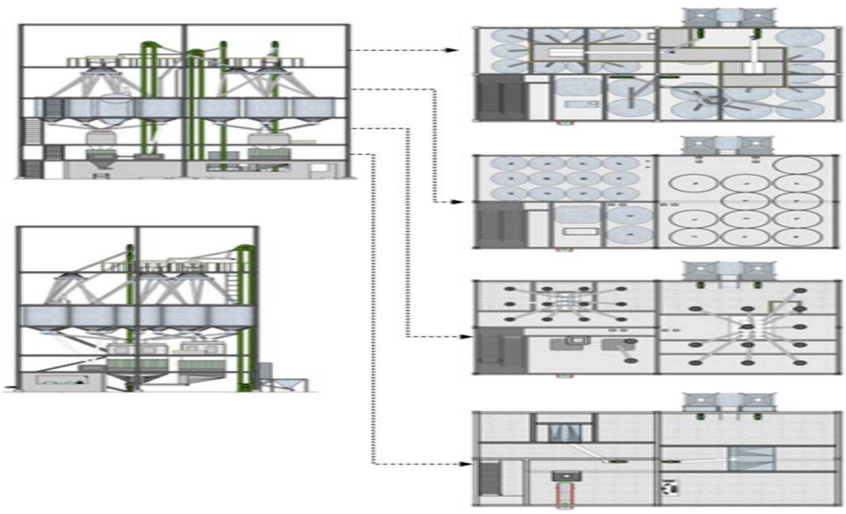


Figure 2. The production area of the factory

3.2 The Problems of the Case Study Factory

The problems can be summarized as follows:

1) The actual production capacity is not known since the production planning relies on the employee's work experiences.

2) Resource planning and preparation are difficult to manage because the real resource consumption is unpredictable.

3.3 Data Collection and Analysis of Imported Data

This step is significant for simulation. The data analysis tool of this research is the Expert Fit® program. The information was collected in the form of time data and was analyzed in terms of the statistical distribution in the program. After analysis, the program chose the best distribution model for the automated dataset. The results of the analysis are demonstrated as following figure:

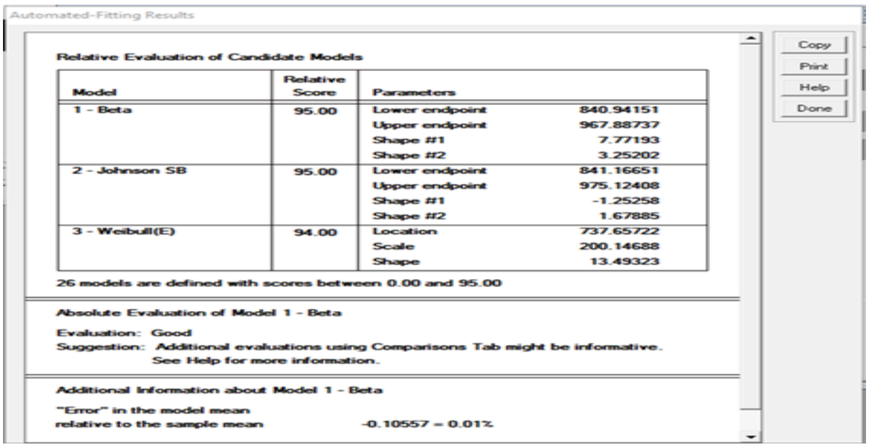


Figure 3. Example of data analysis

Figure 3 shows the best distribution model selected by the program for the automated dataset; the analysis results are shown in the table 1. The researcher chose the best results of the analysis that ranked 1 out of 3.

Table 1. Data Distribution

Procedures	Data distribution in production process	
The production process of mineral concentrate	Johnson	
	Min: 1202.66789	Max: 1317.90983
	Shape1: 0.07686	Shape2: 0.56672
Mineral processing	beta	
	Min: 840.94151	Max: 967.88737
	Shape1: 7.77193	Shape2: 3.25202
Packing	beta	
	Min: 30.80677	Max: 51.37129
	Shape1: 1.04589	Shape2: 1.16804
Sealing	Johnson	
	Min: 9.9169	Max: 19.16951

	Shape1: 0.35020	Shape2: 0.70885
Unload	beta	
	Min: 10.19585	Max: 15.79093
	Shape1: 0.95866	Shape2: 0.99604
Load	Johnson	
	Min: 3.07983	Max: 8.64569
	Shape1: -0.12756	Shape2: 0.51468

Table 1 is the complete distribution model used by the Automated Fitting analysis and selection program used by the researcher to model the current production process of the factory case study. The beta and Johnson fragmentation models include: Distribution (Data Min value, Data Max value, Shape1 value, Shape2 value).

Table 2. The purchase order of minerals in November 2019

Customer	Order	Type	Quantity (Tons)	Due (Day)
1	1	1	20	15
2	2	2	10	25
3	3	3	35	28
4	4	4	6	35
5	5	2	10	40
6	6	2	10	35
7	7	1	30	15
8	8	3	40	45
9	9	3	10	45
10	10	3	30	40
11	11	3	50	30
12	12	3	40	30
13	13	3	20	23
14	14	1	10	12
15	15	3	30	25
16	16	3	10	35
17	17	3	30	30
18	18	1	20	45
19	19	3	10	20
20	20	3	20	30
21	21	3	30	45
22	22	3	10	24
23	23	3	10	20
24	24	3	25	25
25	25	4	4	10
Total			520	

Table 2 presents the simulation sequencing experiment. A case study factory takes 25 trial orders; total production capacity is 520 tons.

3.4 Simulation for the Current Production Process

The simulation model in this research was created by the Flexsim Simulation program. Flexsim Simulation is a 3D modeling software and performs 3D real-time rendering which is capable of simulating the system covering a wide range of industries. The simulation model development of the mineral production process for dairy cows uses Flexsim Simulation 2019 Version 19.0.0. i7-7500 (2.70 GHz-2.90 GHz), Ram 8.00 GB, Redeon (TM) R7 M445 graphics card and by running the Microsoft Windows 10 Home X64 operating system. After the process, the model will be obtained as shown in the following figure.

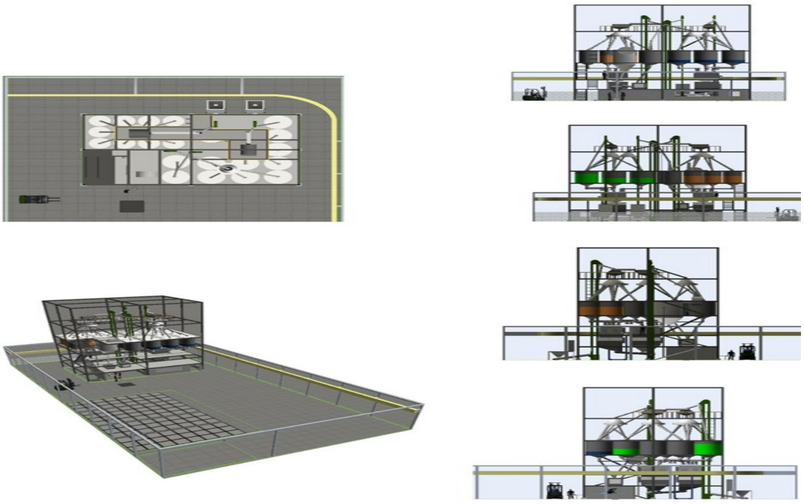


Figure 4. Production process model

3.5 Completeness and Accuracy

The next step of model development is testing. The dairy production process model was tested: 1). the model can be run without any error notification from the program, and 2). the behavior in the model can work properly in a real working environment of the case study factory.

3.6 Validity

The validity of the simulation can be checked by the program "Minitab", which is a software package that is used for data analysis and statistical processing.

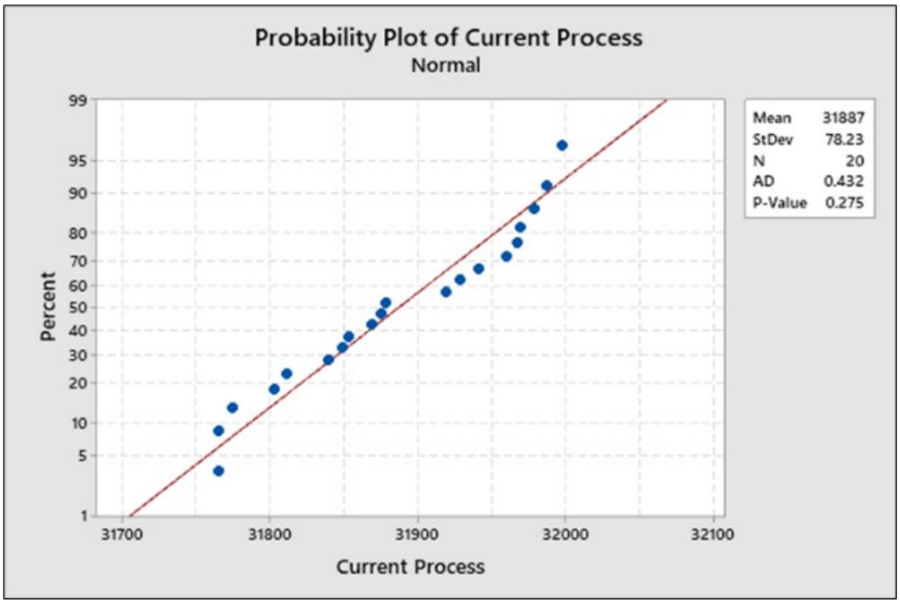


Figure 5. The result of data analysis of the current production process

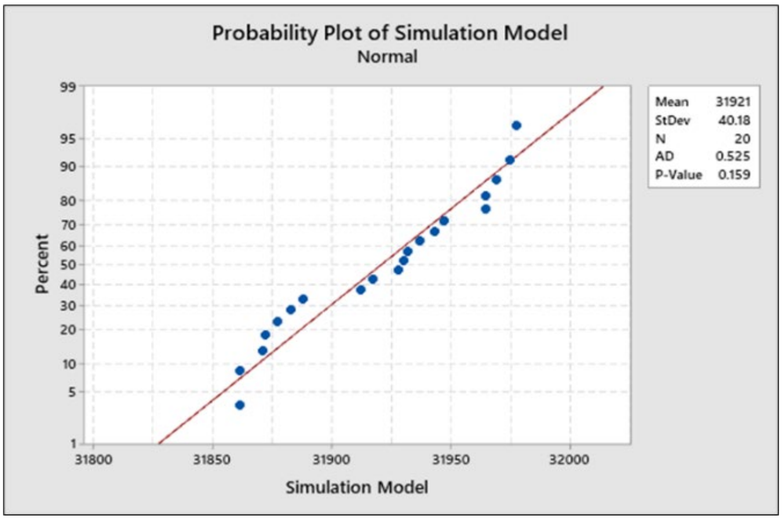
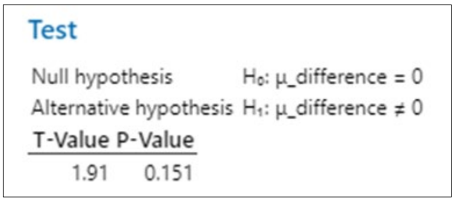


Figure 6. The result of data analysis of the simulation model

From Figure 5 and Figure 6, the Anderson Test results show that the P-Value of the current process is 0.275 and the P-Value of the process model is 0.159. The P-Values of both data were greater than the significance level of 0.05, so it can be concluded that both sets of data were normally distributed. The simulation model was then compared with the current production process in order to check the completeness of the model whether it can replace the current model. A paired T-Test method was used for this comparison; the hypotheses are shown as follows:

H_0 = representative model for enabling production mode

H_1 = representative for disabling production mode



Test

Null hypothesis	H_0: μ_difference = 0
Alternative hypothesis	H_1: μ_difference ≠ 0

T-Value	P-Value
1.91	0.151

Figure 7. Result of the comparison

From Figure 6 and Figure 7, the results of comparing the model with the real system using the Paired T-Test method were found to be 0.151, where the P-Value was greater than the significance level of 0.05. It can be concluded that the simulation can represent the current production process.

3.7 Applying the Model to the Production Sequence

Once the model has passed the completeness and validation process the model can represent the current production process. Therefore, the model is applied to simulate production scenarios in EDD, LPT, and FCFS. The program will arrange the workflows based on the purchase order's information. When the running of the model is finished, the automated information will be shown including production time, date of production, and start and finish date of each order.

4. Results

In the initial process of the experiment, the purchase orders would be uploaded into the program of the simulation model. The production sequence was tested in the forms of EDD, LPT, FCFS (each form was tested in 30 replications). Thenceforth, Duncan's Multiple Range Test was applied to examine the results.

Table 3. The analysis of result's differences (confidence interval is 95%)

Contrast	LPT vs FCFS	LPT vs EDD	EDD vs FCFS
Difference	2.904	2.375	0.530
Standardized difference	17.623	14.409	3.214
Critical value	2.092	1.988	1.988
Pr > Diff	< 0.0001	< 0.0001	0.002
alpha	0.098	0.050	0.050
Significant	Yes	Yes	Yes

Table 4. The data and result analysis of production sequencing

Category	Mean	Lower bound (95%)	Upper bound (95%)	Groups
LPT	166.545	166.313	166.777	A
EDD	164.170	163.939	164.402	B
FCFS	163.641	163.409	163.872	C

From Table 3 and Table 4, it was found that the EDD production sequence is the most appropriate format since the makespan time is 164.170 hours and a tardy job is equal to 0 tons, while the makespan time of LPT is 166.545 hours and the number of tardy jobs is 74 tons. In addition, FCFS has a makespan time of 163.641 hours and the number of tardy jobs is 59 tons. From the experimental results, this means that EDD has the second smallest shutdown time and the least number of tasks.

5. Discussion and Conclusions

From the study, it was revealed that the main issue of the case study factory was designing and planning the production process by their own experiences; they mainly restricted the delivery date and the number of finished products. Moreover, resource planning and preparation were difficult because the actual daily consumption of resources is not known. From the above problems, the simulation model is suitable for the production process planning. Applying simulation techniques is beneficial for the development of a production sequence. The model can be used for various situations and conditions without affecting the actual production system. Furthermore, the model can predict the start and end time of the production. This information will lead to an effective production plan. Moreover, the simulation techniques can be applied to complex solutions which take time to figure out. The effective application of the simulation model also depends on the purpose of its implementation.

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