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SIMULATION FOR PRODUCTION LINE BALANCING OF A LARGE-SIZED FROZEN CHICKEN MANUFACTURER

This study aims to improve the productivity of a large-sized frozen chicken manufacturer in Thailand. We developed 4 models for chicken preparation process. The current and proposed production systems were simulated using the Arena software. We found that under the current system, we could reduce the number of workers at some stations to reduce wages, but we could not reduce the total time. By implementing the ECRS method, we combined 2 stations into 1. This method could reduce both the cycle time and the number of employees. We were thus able to increase worker utilization while reducing the number of employees by 11 persons and lowering labor cost for 279,840 baht per year.

Keywords: *simulation model; ECRS concept; process improvement; frozen meat manufacturing.*

Рунграт Пісучпен, Порнтіпа Онгунарук

МОДЕЛЮВАННЯ ЗБАЛАНСУВАННЯ ПРОДУКТОВОЇ ЛІНІЇ ДЛЯ ВЕЛИКОГО ВИРОБНИЦТВА МОРОЖЕНОГО М’ЯСА КУРКИ

У статті поставлено за мету підвищити продуктивність виробництва мороженого м’яса курки на прикладі великого виробника в Таїланді. Представлено 4 авторські моделі процесу виготовлення м’яса. Чинна система виробництва порівняна з 4 змодельованими в програмі "Arena". У рамкаї чинної системи можна було б скоротити кількість робочих на деяких станціях і таким чином зменшити витрати на заробітну плату, однак загальний час виробництва в такому випадку не зменшується. При впровадженні ж логіки Кайдзен можна об’єднати дві станції в одну. І таким чином скорочуються і час на обробку м’яса, і кількість співробітників. У запропонованому варіанті кількість робітників скорочена на 11 осіб, а заощадження на заробітних платах становить 279,840 бат на рік.

Ключові слова: *імітаційна модель; логіка Кайдзен; покращення процесів виробництва; виробництво мороженого м’яса.*

Форм. 4. Рис. 5. Табл. 2. Літ. 27.

Рунграт Писучпен, Порнтипа Онгунарук

МОДЕЛИРОВАНИЕ СБАЛАНСИРОВАНИЯ ПРОДУКТОВОЙ ЛИНИИ ДЛЯ КРУПНОГО ПРОИЗВОДСТВА ЗАМОРОЖЕННОГО МЯСА КУР

В статье поставлена цель – повысить продуктивность производства замороженного мяса кур на примере крупного производителя в Таиланде. Представлены 4 авторские модели процесса подготовки мяса. Действующая система производства сравнена с 4 смоделированными в программе "Arena". В рамках действующей системы можно было бы сократить количество рабочих на некоторых станциях и таким образом уменьшить расходы на зарплату, однако общее затраченное время в таком случае не сокращается. При внедрении же логики Кайдзен можно объединить две станции в одну. Таким образом, сокращается и время обработки мяса, и количество работников. В предложенном варианте количество работников сокращено на 11 человек, экономия на зарплатах составит 279,840 бат в год.

Ключевые слова: *имитационная модель; логика Кайдзен; улучшение процессов производства; производство замороженного мяса.*

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Introduction. In Thailand, agro-industry is a major economic driver. One of major imported products is chicken (United Nations Statistics Division, 2012). We are interested in implementing a simulation model to mimic the production process so that we do not need to actually change production processes before knowing whether the result is better. In this study we focused on improving a frozen fried chicken process since it had the highest demand and the shortest order lead time.

Problem statement and research objective. From the observation of manufacturing processes, we found that the bottleneck operations are labour-intensive tasks such as battering and powdering (Figure 1). These operations can be categorized into 6 distinct jobs: handling chicken, weighing chicken, weighing batter, battering, delivering battered chicken and powdering.

The objective of this study was to improve the productivity of a large-sized frozen chicken manufacturer in Thailand. Production process was analysed based on productivity improvement principles. Next, we developed 4 simulation models to mimic the chicken preparation processes and to compare the performance of individual models. Finally, we suggested the best simulation model to be applied in real production.

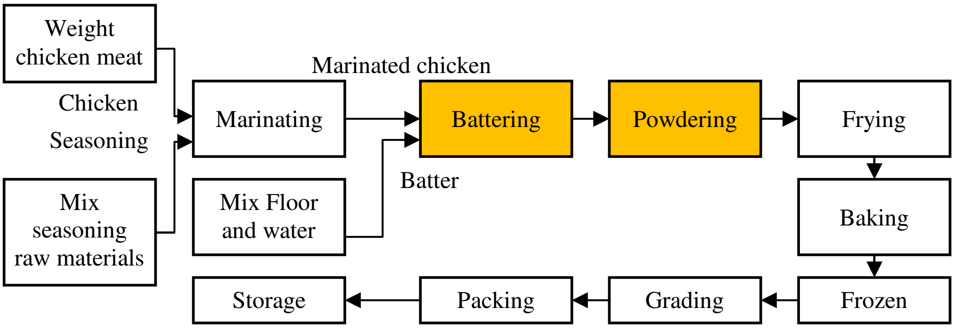

Figure 1. **Frozen fried chicken production process,** *authors'*

Literature review. The related concepts implemented in this case study have been reviewed first. This study reviewed the process improvement basing on the ECRS concept. ECRS was implemented in many industries such as in a canning line of a Suntory factory that produced beer and soft drinks to reduce changeover time (Koichi, Hideki and Tsunehiko, 2006). In addition, there were some case studies that implemented both ECRS and line balancing. G. Lathkar (2012) used ECRS to increase productivity in autoindustry of India. In China, L. Zhao (2012) used ECRS and line balancing to increase production line efficiency in the assembly line. W.X. Yao (2012) implemented line balancing, 5W1H and ECRS for productivity improvement in server production. Similarly, in Thai industries, there were several implementations of process improvement by ECRS, as follows. K. Sritarathorn et al. (2010) used 5W1H and ECRS to reduce the visual inspection time and the total repair processing time in the biodegradable packaging process. Next, C. Kasemset et al. (2013) proposed a motion study combined with ECRS to increase the productivity of a plastics packaging factory. Other studies that implemented the lean concept in assembly line balancing were as follows. V. Laemlaksakul et al. (2013) increased the productivity in the frozen food industry using line balancing, skilled labour development and layout design. Y. Li (2012) proposed lean production for a car seat assembly line to reduce production cycle and inventory costs. Time study and operational analysis were implemented in the assembly line of an automobile manufacturing company for process improvement and labour productivity increment as in H. Sabatini et al. (2010).

Simulation is a well-known technique for analyzing systems or processes by imitating their behavior using physical or mathematical models. There are two types of system: static and dynamic. Behavior of a static system does not change over time, whereas behavior of a dynamic system changes over time (Law and Kelton, 2000; Ragsdale, 2004). Simulation is widely used for solving line balancing such as in (McMullen and Frazierb, 1997; Lyu, 1997; McMullen and Tarasewich, 2003; Mendes et al., 2005; Rajakumar et al., 2005; Villarreal and Alanis, 2011); Fan et al., 2010). In addition, simulation can be implemented in other problems such as machine load balancing (Ali et al., 2011), scheduling and sequencing problem (Costa and Ferreira, 1999; Lalas et al., 2006; Bekki et al., 2009) and in minimizing production costs (Khan, 1999).

This research employed a method similar to that of K.S. Al-Saleh (2011), who performed motion and time studies to improve productivity of a motor vehicle inspection station. First, he identified the bottleneck operation of the motor vehicle inspection process. Then, the number of samples was calculated in order to determine the task time. Next, he calculated the normal time and the standard time for each task. Then he proposed the methods using the ECRS concept to improve productivity. Finally, the output of the proposed method was simulated using the ARENA software. However, in the present research the proposed methods were actually implemented in production process and the resulting output was recorded. In this case study, the cycle time in each station was varied by operator skill. Hence, we proposed a simulation model to mimic the actual production and analysed several scenarios to determine the best one basing on the selected situations. In addition, P. Ongkunaruk and W. Wongsatit (2014) studied an ECRS-based line balancing concept for the same company. Our research aims to present how we can simulate the production processes to determine the best method to improve productivity without interfering into the current production lines.

Research methodology.

The study of production line. After analysis of the current production line by drawing the precedence relationship of the production line, there were two major deficiencies: low productivity and high labour costs. We then proposed 4 methods utilizing the theory of constraint, JIT, ECRS and Kaizen concepts, and implemented them in production.

Simulation model building. In this section, we explain the simulation methodology and how to build a simulation model using Arena. We used a simulation model as a tool in this study since it mimics the actual production system that had uncertain input parameters such as processing time and thus we could experiment with the model by varying the number of operators at each station to determine the optimal number of operators. In this study, we selected a well-established commercial simulation software, "ARENA", to simulate the production system.

The input data analysis. First, we collected the production quantities (from November 2009 to December 2010) and selected a product that had continuous orders and low productivity. Then, we analysed the production process of the selected product. We identified task description, precedence relationship and bottleneck operation. Next, we recorded the processing time of the selected process using the right number of replications. Finally, we studied the processing time distribution of each station. We set the hypotheses of input data as follows:

H_0: the processing time is independent and identically distributed.

H_1: the processing time is not independent and identically distributed.

At the 95% confidence interval, we tested the assumptions of processing time. If the P-value of the statistical result was more than 0.5, we would accept H0. Then, we used input analyser in ARENA (version 13) to determine the best distribution.

The simulation model. Next, we simulated the current and the proposed production processes. The Create module generated raw material with a constant 10 kg per minute and 4,200 kg of total raw material per day. Then, we defined the total simulation time as 10 days and the total raw material was 42,000 kg, which was the customer requirement per month. The validation of the simulation model is completed by comparing the total time of the actual system with the simulation system. The hypothesis testing for comparing means is conducted at $\alpha = 0.05$. The total time from both systems is not significantly different. Therefore, the simulation model can be used to represent the current production system.

The output analysis. We implemented the line balancing concept by varying the set of number of operators that balances the line so that the number of experiments was reduced. Then, we could balance the line by allocating 1 operator in station 1 and 2 operators in station 2 to minimize the waiting time. Next, we varied the number of employees in the process analyser for feasible scenarios and selected 58 scenarios to study. Finally, we analysed the results of simulation and selected the best production model to improve the production line efficiency. We studied several key performance measurements such as the number of employees, resource use, number of works in process (WIP), total wage costs and total time.

Key results.

Process improvement from existing condition. P. Ongkunaruk and W. Wongsatit (2014) found that the workers did not want to change and have a resistance to any changes in production lines. Hence, we propose to study the simulation model for production process improvement without interfering with the current production lines. We proposed 4 simulation models varying the number of workers at each station to determine the best models.

Proposed Model 1. Considering the sequence of processes from the precedence relationship in Figure 1, we used the lean concept by minimizing the waiting time that job C must wait until job B is done. Then, we ensured that jobs B and C could be operated simultaneously. A network model and simulation model are shown in Figure 2. Note that the differences between the current model and Model 1 were that in the latter we added the Separate, Match and Batch modules to represent the parallel operations between jobs B and C. The Separate module assigned raw materials to be done separately. Then, jobs B and D were processed while job C was processed. After jobs C and D were done, the work in process was matched via Match and Batch modules. Job E started afterwards. The downstream processes were similar to that of the current model. The total cycle time was calculated by using

$$TC = Max\{C_A + C_B, C_C\} + C_D + C_E + C_F. \quad (1)$$

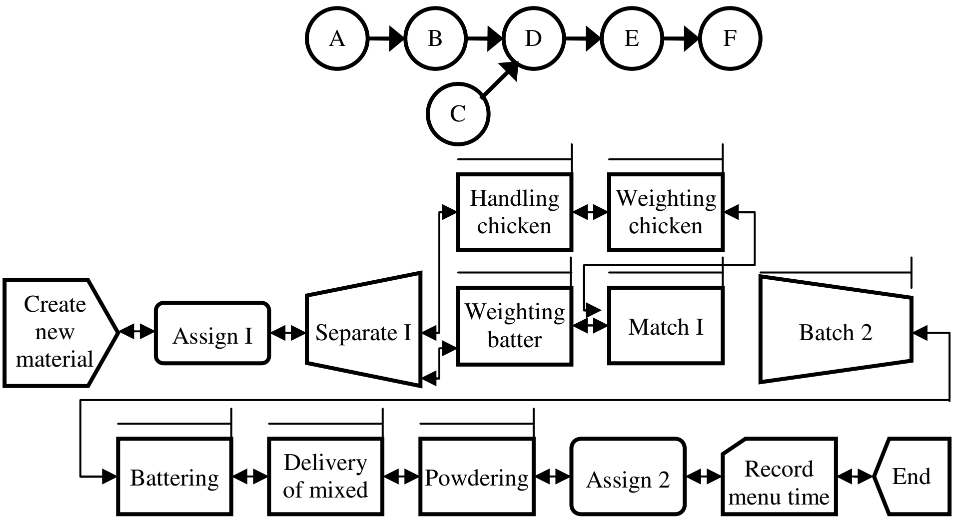

Figure 2. **Proposed Model 1,** *authors'*

Proposed Model 2. In this model, we implemented the Kaizen concept, which continuously improves Model 1 by assigning jobs B and C to the same station, so they would be operated simultaneously using the fixed number of operators. A network model and simulation model were similar to that of Model 1 except that resources in jobs B and C issued in the Resource spreadsheet module was the same set of operators as shown in Figure 3. The total cycle time was calculated by using

$$TC = C_A + C_{BC} + C_D + C_E + C_F. \quad (2)$$

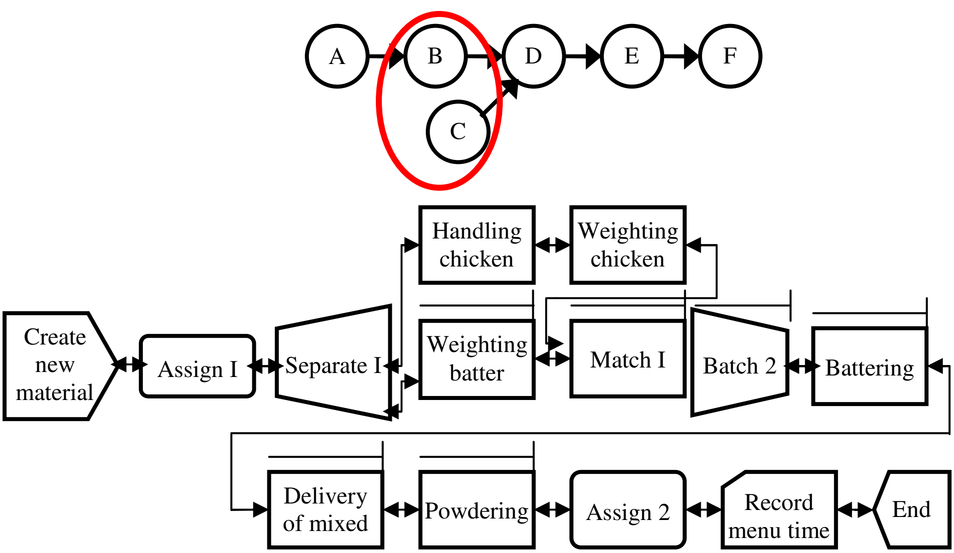

Figure 3. **Proposed Model 2,** *authors'*

Proposed Model 3. In this model, we implemented the ECRS concept by combining jobs A and B at the same station. This implied that each operator at this station would handle and weigh chicken as shown in the simulation model, in which chicken handling (job A) and chicken weighing (job B) were in the same module. Then, we assigned the same set of operators in the Resource spreadsheet module. This combination could reduce the total time of jobs A and B since they were done by different operators. At the same time, the processing time was increased, while job C was assigned to another station. Then, the operators who worked for job C would work at the same time as the operators who worked for jobs A and B. Hence, the waiting time was eliminated. Next, we simplified job E by using a cart to carry chicken instead of carrying it by hand. A network model and simulation model are shown in Figure 4, which is similar to that of Model 2 except that there is the combination of jobs A and B in one module. The total cycle time was calculated by:

$$TC = Max\{C_{AB}, C_C\} + C_D + C_E + C_F. \quad (3)$$

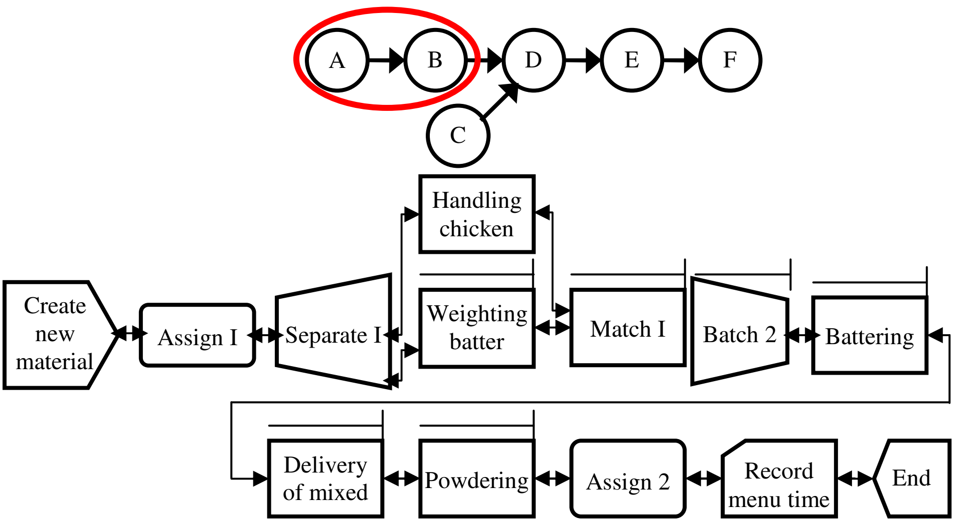

Figure 4. **Proposed Model 3,** *authors'*

Proposed Model 4. In this model, we continuously improved Model 3 by assigning jobs C and D to station 2 (Kaizen and ECRS concepts). Next, we created a network model and simulation model as shown in Figure 5, which was similar to Figure 4. However, jobs A and B were done by the same operator in the same set of resources under the Process module. Next, the number of resources was issued in the Resource spreadsheet module. Similarly, jobs C and D were done by the same operator, represented as the same resource name in the Process module. The total cycle time was calculated by:

$$TC = C_{AB} + C_{CD} + C_E + C_F. \quad (4)$$

Comparison of the current and the proposed models. After running the simulation of all these models, we compared the current model with the 4 proposed ones by plugging in the current number of employees. After running, we checked the utilization rate of work stations, total wages, works in process (WIP) and total time as shown in

Table 1. The results showed that if we did not reduce the number of operators, then the proposed models were better off as the WIP and total time were reduced. However, the utilization rate of the operators for jobs D and F were quite low. This implied that we could reduce the number of operators for these jobs.

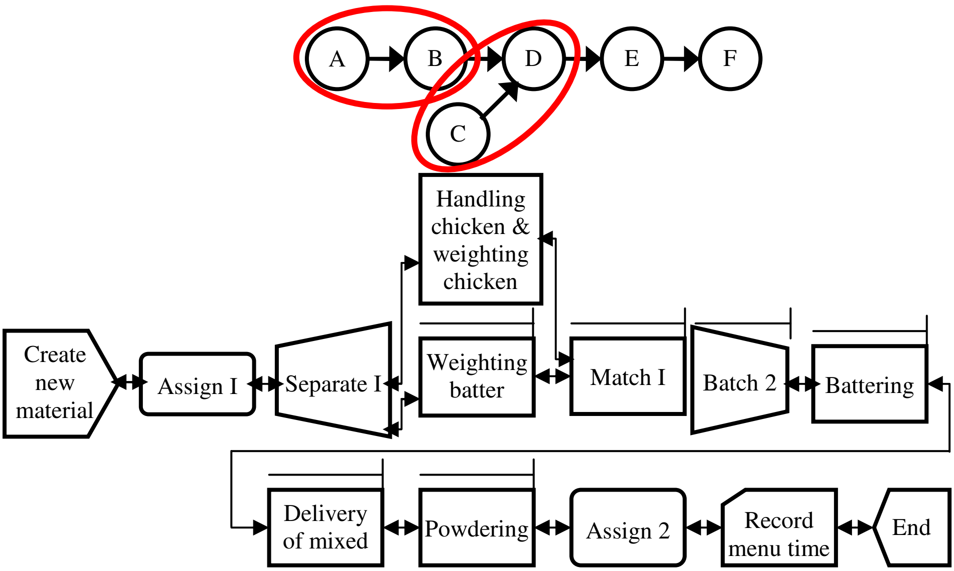

Figure 5. **Proposed Model 4,** *authors'*

Table 1. **Comparison of the current method and the 4 proposed methods,** *authors'*

Description/ stations		Models				
		Current	1	2	3	4
# of employees	A	1	1	1	3	3
	B	2	2	4		
	C	2	2		2	11
	D	9	9	9	9	
	E	3	3	3	3	3
	F	18	18	18	18	18
Utilization	A	0.78	0.78	0.78	0.73	0.73
	B	0.71	0.71	0.71		
	C	0.71	0.71		0.71	0.48
	D	0.42	0.42	0.42	0.42	
	E	0.76	0.76	0.76	0.76	0.76
	F	0.57	0.57	0.57	0.57	0.57
Daily wages (baht)		7,420	7,420	7,420	7,420	7,420
WIP (kg)		23.752±0.02	22.289±0.02	23.718±0.02	21.456±0.02	21.377±0.02
Total time (sec)		152.693±0.14	143.288±0.12	152.474±0.15	137.931±0.12	137.423±0.12

Next, we used the process analyser, which is the tool in Arena to optimize the resource allocation. Our objective was to determine the suitable number of employees while still maintaining the customer requirement without overtime production.

Then, we implemented the line balancing concept to estimate the lower and the upper bounds of the number of operators and put these numbers into the simulation model. After that we ran the simulation and selected the scenarios that fulfilled our objective. Then, we showed 58 scenarios in which there was no overtime production. We observed that we could reduce the number of operators in jobs D and F. In our study, we tried to reduce at most 5 operators for job D. However, if we reduced 5 operators, then WIP and total time were increased dramatically. This implied that we could reduce at most 4 operators in all the models except Model 4. We found that in Model 4, we combined jobs C and D at the same station and the total number of operators could be reduced to 6. This implied that the number of operators was reduced by 5 in this model as seen in scenario 58. We suggested that since the operators at the same station could do two jobs at the same time and the utilization was increased, the 6 operators were sufficient for completing jobs C and D.

Table 2. **The best simulation scenarios,** *authors'*

Values at station		**Scenario number**				
		48	**50**	**56**	**57**	**58**
		Model 3	**Model 3**	**Model 4**	**Model 4**	**Model 4**
# of employees	A	3	3	3	3	3
	B					
	C	2	2	8	7	6
	D	5	5			
	E	3	3	3	3	3
	F	13	12	12	12	12
Utilization	A	0.73	0.73	0.73	0.73	0.73
	B					
	C	0.71	0.71	0.65	0.75	0.87
	D	0.76	0.76			
	E	0.76	0.76	0.76	0.76	0.76
	F	0.79	0.86	0.86	0.86	0.86
Total number of workers		26	25	26	25	24
Daily wage (baht)		5,512	5,300	5,512	5,300	5,088
WIP		21.269±0.04	21.741±0.04	21.568±0.04	21.824±0.04	22.37±0.04
Total time (sec)		139.044±0.2	139.767±0.2	138.65±0.2	140.293±0.2	143.83±0.2

Later, we selected the 5 best scenarios by considering the total number of employees and total time (with no overtime production), as shown in Table 2. This showed that when the number of operators was reduced, we could reduce wage costs and increase the utilization rate, especially in jobs D and F. However, the total time could not be reduced using the current production system. Then, we observed that the proposed models could reduce the total time and WIP. However, some scenarios increased the total time and WIP as mentioned previously. In general, Model 1 increased the production efficiency. Model 2 could reduce the number of workers, but could not reduce the total time and WIP, while Models 3 and 4 were more efficient if we allocated the right number of workers to each station. Next, we selected 5 scenarios of Models 3 and 4 with lower total time, WIP and total wages than the current system to compare with each performance indicator. Then, we were able to select a scenario based on particular criteria. For example, if the company wanted to minimize total wages, it should select scenario 58. On the other hand, if the goal was to minimize the total time, it should select scenario 48 or 56.

Finally, we selected scenario 58 from Model 4, which outperformed other scenarios from the labour cost point of view. We were able to eliminate 11 operators, thus reducing wages from 7,420 to 5,088 baht per day, or 279,840 baht per year. By implementing this we could also reduce the total time from 152.693 ± 0.14 to 143.83 ± 0.2 seconds and WIP from 23.752 ± 0.02 to 22.37 ± 0.04 kg. In addition, we could increase worker utilization at station 3 by combining jobs C and D. However, reducing the number of employees involved in preparation processes from 26 to 24 resulted in increased WIP and total time, in accordance with Little's law. Comparing the results with (Ongkunaruk and Wongsatit, 2014), the best model was the same. Hence, the simulation model can be a tool for decision-making and can save some time on trials and errors in actual production.

Conclusion. The purpose of this study was to improve the productivity of frozen chicken preparation process so that the case study company could better serve its customer's requirements. The study showed that although large-sized company has high-quality management standards and good manufacturing practices including a traceability system, there was still room for improvement in production processes. By using the simulation modelling, the company could select the most suitable model for improvement by particular criteria such as total time, worker utilization, WIP and total wages without changing the production line. The current production system was inefficient since it required too many operators, low utilization rate and much time. By applying line balancing and the ECRS concept, we were able to increase production efficiency and reduce the number of operators in the production line with a low utilization rate using Models 3 and 4. After selecting the method and the scenario, the company could implement them in real life.

In summary, most agroindustry manufacturing processes are labour-intensive. Thus, to increase productivity and reduce costs, simulation can be used as a decision tool to design an efficient production system. We found that the case study company had designed the production line without aligning it with the production network. A simple improvement could be made by adjusting the sequence of work. In addition, the current production line was not lean.

Further investigation. Implementation of the ECRS concept to improve production could reduce the waiting time and simplify the job. Using simulation, manager is able to decide which production system is the best, based on the company goal, without disturbing real production. Hence, this case study provides an excellent example for other manufacturers on how to improve productivity and increase competitiveness.

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