The Development of the Production Model by Using the ARENA Simulation Software: A Case Study of a Toy Factory in Thailand

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Abstract

The purposes of this study were as follows: 1) to study the queueing system of the toy factory with the simulation model, 2) to analyze the events in the toy factory by creating the queueing system model from the real data with ARENA and calculating the average waiting time of the system of each position in order to create the new model, and 3) to provide alternative solutions for enhancing the production performance of the company. The results of the study revealed that the average production time for a product was 382±15.56 seconds. The product checking system was developed, and the additional channel for checking the products was opened. By modifying the channels and systematically producing the products by opening the additional channel, it was found that the production time was 124±2.35 seconds. It was faster than the original time at 251.67 seconds.

Keywords: Simulation Model, Waiting Time, Queueing System

Introduction

The growth rate of the toy industry is high because of economic wars that may provide new opportunities for industries such as the toy industry. The United States of Americas imported over five billion dollars. Seventy four percent of the imported products were from China, while the Thai products exported to USA were only 200 million dollars. In 2017, the export volume of the Thai toys was increased for 11% because the USA and Japan imported the Thai toys more than the previous years. Since the toys from China became more expansive because of the import duties and the Chinese manufacturers faced the increased costs of raw materials, Thailand had to find the opportunities in new markets. The market providing business opportunities is the "toy market" (Krungthai, 2019). This was consistent with the Ninth National Research Policy and Strategy including the fourth research strategy promoting mechanisms and activities applying research methods, findings, knowledge, innovations and technologies by having the coordination with sectors (National Strategy (2018 - 2037).

Production management is an important part of logistic processes. If the production management is efficient, then companies' costs will be reduced. There are three main components: input, conversion process and output. It was found that production activities had long product verification periods that led to production costs. The main goals of manufacturing plans are to reduce the production costs and to improve the variety and qualities of products. Ulutas and Islier (2015) created computer models that could be used for eliminating bottlenecks, efficiently using resources and improving the performances of systems before modifying the existing systems by automatically creating designs. According to Han et al. (2012), time is basically wasted without adding any value to the time. On the other hand, the time may be used for production in production lines. Regarding to Stadnicka (2015), production waste management could provide spaces and improve efficiencies. According to Rybicka et al (2015) and Jayal et al., (2010), workers should emphasize on time reduction in order to meet production goals. By referring to Mustafa and Cheng (2016), factories must follow and collect data as well as focus on appropriately exchanging the data in order to improve efficiencies. Huyet (2006) developed automatic simulation models with ARENA for production that can be quickly adjusted according to dynamic requirements. Real-time data were presented by Kuehn and Draschba (2004). Computer models could be used for eliminating bottlenecks and improving the performances of systems before modifying the systems. The designs from automatic systems were presented. Production plans could facilitate and improve the structures of simulated models. Main benefits were related to processes and activities. According to Terkaj, Tolio and Urgo (2015), the importance of the production systems of the toy industry was found. One factory was selected as the model for studying the production models. In this case, there were two types of toys including train toys and airplane toys. After painting pieces, the pieces are sent the inspection unit having one inspector. In each inspection, two similar pieces were inspected. This process was time consuming. The factory still did not have a data analysis system. Therefore, profits were reduced. This might affect customer services as explained by Han et al (2012). According to the stated problems, the balance of production lines was emphasized by the researcher (s) in order to have efficient operations. The positions of the employees must be specified by the researcher (s) and the systems must be appropriate for the production by applying Arena simulation to the business since the program was important for the organization in order to identify the time period of each production process. The production model could be adjusted in order to reduce errors and costs as well as to facilitate and quicken operations.

Objectives

1. To study the queueing system of the toy factory with the simulation model
2. To analyze the events in the toy factory by creating the queueing system model from the real data with ARENA and calculate the average waiting time of the system of each position in order to create the new model
3. To provide alternative solutions for enhancing production performance of the company

Concept and Theory

Simulation

Simulation is the collection of methods for simulating the situations or activities of systems on computers by using software in order to study the flows and patterns of the activities. Data are collected, and correct patterns are identified with the software for further improvements Kelton, Sadowski and Sadowski (2003). Since real operations cannot be experimented or adjusted until benefits are identified (e.g., solving unexpected problems slowing down the production processes), simulations can enable analyzing the current situations of the systems and find appropriate guidelines or scenarios before being applied to the real situations or operations in order to lower the risks of errors or failures and to reduce costs and time Maria (1997). Presently, the simulations are widely used because of the progressive development of computer systems. Hence, the simulations can be applied to many industries such as industrial factories, transportations, product distribution or business services of banks, hospitals and other organizations (Kelton et al., 2003).

Queuing Theory

The queuing theory is the creation of mathematic models in order to predict possible events if there are people in any queue. Generally, the basic structures of the queuing theory can be presented in the following figure.

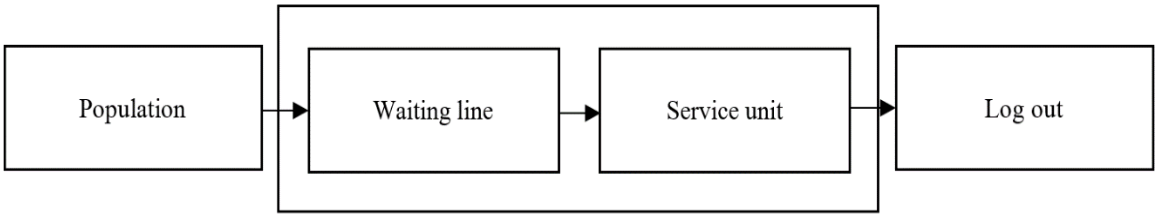

Figure 1 Pattern of the queuing system (Jamnarnwej, 2009)

Vanichbuncha (2006) specified the forms of the queuing theory as follows.

1. Single Channel-Single-Phase System is a system with only one channel and one phase.

2. Multichannel and Single-Phase System is a system with only one phase, but it has many channels for customers to choose.

3. Multiple –Channel-Single – Phase System is a system with only one phase, but it has many channels.

4. Single Channel-Multiple-Phase System is a system with each channel having many phases.

5. Multiple-Channel-Multiple-Phase System is a system that customers can use services passing many phases.

Suchithra Rajendran (2021) studied Real-time dispatching of air taxis in metropolitan cities using a hybrid simulation goal programming algorithm. The results of the experimentation suggest that the minimum number of air taxis required for efficient operation in NYC is 84, functioning with an average utilization rate of 66%. In addition, the impacts of commuter’s “willingness to fly” rate, percentage of demand fulfillment, on-road travel limit, maximum customer wait time, and arrival distribution on the optimal number of air taxis, utilization rate, number of customers served, and cost incurred per customer are examined.

Pan et al (2020) studied the creation of the intermittent production industry model (s). It was found that simulating the intermittent production events by using ARENA was for studying the flows of the holders of the aluminum brakes in the factory and finding the bottlenecks in order to calculate the production volume and the needs for the workers in the units. The plans of the processes of the aluminum holders and the processing time of each process were calculated by using ARENA. Then, the results were inputted into the software and simulated in order to improve the results of other instruments. The bottlenecks were found, and the better model(s) were suggested. It was found that the production volume was increased for 6% and the needs of the labors were decreased for 8.33% as compared to the (actually) existing factory model.

Wang Pan et al., (2019) studied Integrating multi-functional space and long-span structure in the early design stage of indoor sports arenas by using parametric modelling and multi-objective optimization. Diverse solutions with three frequently used structural types. The framework of assessment criteria includes indicators of viewing quality for spectators, acoustics, and structures, which can evaluate the design in different aspects. Based on certain assessment criteria, the MOO can be used to search for good designs in the broader space, and the post-process tools facilitate the designer to analyze the results. Two typical arenas (the Barclay Centre and the O2 Arena) are selected as real case studies to demonstrate the proposed process and assess the capacity. Results of the case studies validate the efficacy of the process and the necessity of the broader design space to include diverse solutions with multiple structural types.

Jilcha et al., (2015) studied the creation of the performance models of the workers and machines in the production system with Arena Simulation. It was found that measuring the performances with the simulation of the intermittent production system was relevant to the creation of the models, by improving the data transfer time (s) for creating the queuing system model (s). The simulation of ARENA was developed and verified in order to identify the daily productions and possible problems at the different levels of requests in Case Company (i.e., an Ethiopian plastic factory). The results showed that the remaining time (s) in the system was short because of the bottlenecks and times to be identified. Hence, some basic suggestions were from the results for emphasizing the importance of considering and improving the performances of the machines in the mentioned model (s).

Research Methodology

Method

This study was a case study. The company was a small sized business without any logistic management system and efficient supply chain.

Instrument

Arena Simulation was used for creating the model of the events.

Data Collection

The in-depth data were studied in the organization (AS-IS Model). The production processes and times were studied and measured.

Data Analysis

The data were analyzed with Arena Simulation in order to compare the followings.

1. The average time spent by the conventional system and that of the new system
2. The average waiting time of the conventional system and that of the new system

The production lines were not balanced because the products must be painted. The positions of the workers were also not appropriate. This caused the delayed productions and costs as summarized in Table 1.

Table 1 Lead time and number of pieces in the production line

Operating Procedure	Train (Min/Piece)	Airplane (Min/Piece)	Employee (Person)
Parts coming into the production line	5	9	2
Painting	3	3	3
Check Product	5	5	1

According to the table of the data collection within a day, the employees could averagely produce 80 toy trains and 50 airplane toys. The mentioned data were analyzed with the First In First Out (FIFO) method without no one leaving the queue as shown in Figure 2.

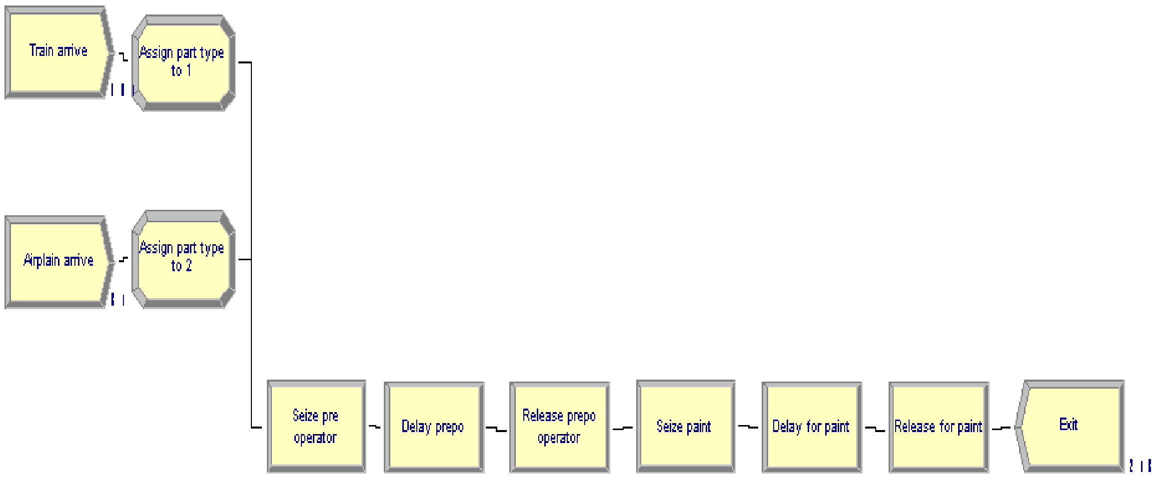

Figure 2 Scenario models in Arena Simulation

Figure 2 can be explained as follows.

1. The time(s) and the amount(s) of the toys in the production line(s)
2. The properties and timer(s) of the preparations of the parts of the train toys and airplane toys
3. The positions of the three painters
4. The delay(s)
5. The period(s) before the workers releasing the parts
6. The painting period(s)
7. The delay(s)
8. The period(s) before the workers releasing the products
9. The exit of the system

Model Verification

The model was verified by the researcher(s) by comparing the results of the model and the data from the real system. The total time that the parts were in the system was considered as affected by the waiting times of the parts being queued to be painted. It was found that the time was close to the real value at the confidence level of 95%. By comparing the total time of painting the parts of the simulated system and that of the real system, it could be summarized that the created model was not different from the real system at the confidence level of 95%.

Results and Discussion

The comparison of the results of the model and that of the actual system is shown in Table 2.

Table 2 Comparison of results from simulations and real systems

Data Result	Real System (Mean±SD)	Simulation Model
Waiting time (seconds)	76.45±92.32	84.65±14.32
System time (seconds)	375.67±101.23	382±15.56

The production model of the toy factory before painting the toys was modified. In the cases of two toys waiting for the services, the train toys would be always prioritized if the parts were prepared by adding a flow and channel for painting the toys.

According to the simulation results, the waiting time of the parts in the production system at the confidence level of 95% was 382±15.56 seconds. The long waiting time was caused by only one channel for painting the toys that was not enough. Thus, the researcher(s) simulate the additional channel that was open only if there was any part waiting for the painting process for longer than one minute as shown in Figure 3.

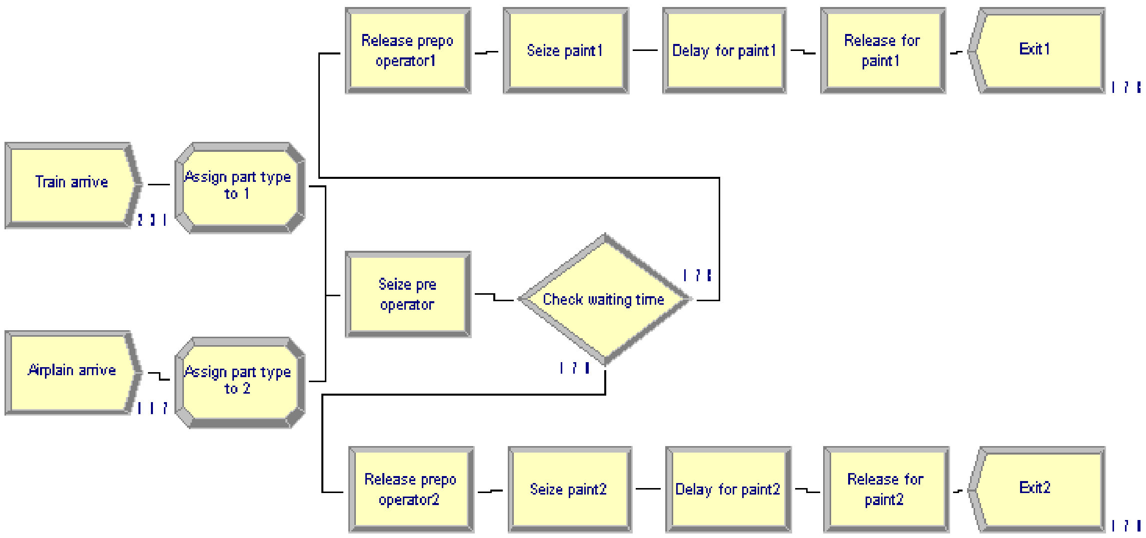

Figure 3 Simulation of the opening channel for painting, add one channel in the Arena Simulation program.

Table 3 Comparison of the situation before and after adding a paint channel

Data Result	Value obtained from adding production lines	
	before adding	after adding
Waiting time (seconds)	76.45±12.23	5.45±1.23
System time (seconds)	375.67±11.12	124±2.35

By simulating the additional channel for painting the toys, it was found that the waiting time was reduced to 251 seconds.

Conclusion

1. The production lines were not balanced Kriengkorakot (2013). Work study is a word that refers to the study of any work and working time before creating any system from all results in order to improve any performance. This is consistent with this study about the production times for making production plans, managing production lines and achieving production goals. There are problems including long production times and failures to achieve the goals.

2. ARENA simulation is a method that has been used for solving problems for a long time, and the number of people interested in it is increasing because of advanced computers and problem simulation models of real systems.

Suggestions

In the future, will be researched and developed using the proposed Theoretical framework. It will be tested and validated using practical data. The issues of permanent adaptations and removal of inefficient flowing items are suggested to be addressed to make the system more practical. In this paper, the manufacturing environment is assumed to be deterministic; By applying the findings to simulating current and future situations, situations can be identified, and decisions can be made conveniently before practices. Additional information technology techniques or system should be studied in order to maximize benefits for productions and improve systems. Other variables with direct and indirect effects on production systems should be studied.

References

Han, S.H., Al-Hussein, M., Al-Jibouri, S.H.S., and Yu, H. (2012). Automated post-simulation visualization of modular building production assembly line. Automation in construction, 21, 229-236.

Huyet, A.L. (2006). Optimization and analysis aid via data mining for simulated production systems. European Journal of Operational Research, 173(3), 827–838.

Jamnarnwej, K. (2009). Quantitative Analysis. Retrieved December 18, 2020, from: http://watha.gendit.com/208440-1-2554/Ch1-2.pdf (in Thai).

Jayal, A.D., Badurdeen, F., Dillon, O.W. and Jawahir, I.S. (2010) Sustainable Manufacturing: Modeling and Optimization Challenges at the Product, Process and System Levels. CIRP Journal of Manufacturing Science and Technology, 2, 144-152.

Jilcha, K., Berhan, E. and Sherif, H. (2015) Workers and Machine Performance Modeling in Manufacturing System Using Arena Simulation. Journal of Computer Science & Systems Biology, 8(4) 185-190.

Kelton, W.D., Sadowski, R.P. and Sadowski, D.A. (2003). Simulation with Arena. Retrieved December 18, 2020, from: https://web.iitd.ac.in/~nomesh/MEL770/kelton.pdf

Kuehn, W. and Draschba, C. (2004). Simulation based job shop production Analyser. Proceeding's 18th European simulation multi conference graham Horton (c) SCS Europe. Retrieved from: http://scs-europe.net/services/esm2004/pdf/esm-24.pdf

Krungthai. (2019). Economic Outlook 2019. Bangkok: Krungthai Macro Research. (in Thai).

Kriengkorakot, N. (2013). Industrial Studies. Ubon Ratchathani: Faculty of Engineering Ubon Ratchathani University. (in Thai).

Maria, A. (1997). Introduction to Modeling and Simulation. Proceeding of the 1997 Winter Simulation Conference 1, 7-13.

Mustafa, K. and Cheng, K. (2016). Managing Complexity in Manufacturing Changeover A Sustainable Manufacturing-Oriented Approach and the Application Case Study. ASME 2016 11th International Manufacturing Science and Engineering Conference, June 27–July 1, 2016 Blacksburg, Virginia, USA.

National Strategy (2018 - 2037). (2018). Government Gazette. 135 (82ก), 1-71. Retrieved September 29, 2019, from: http://www.ratchakitcha.soc.go.th/DATA/PDF/2561/A/082/T_0001.PDF (in Thai)

Pan, W., Sun, Y., Turrin, M., Louter, C. and Sariyildiz, S. (2020). Design exploration of quantitative performance and geometry typology for indoor arena based on self-organizing map and multi-layered perceptron neural network. Automation in Construction, 114, 103163.

Rybicka, J., Tiwari, A., Campo, P.A.D. and Howarth, J. (2015). Capturing composites manufacturing waste flows through process mapping. Journal of cleaner production, 91, 251-261.

Stadnicka, D. (2015). Setup Analysis: Combining SMED with other tools. Management and Production Engineering Review, 6(1), 36-50.

Suchithra Rajendran (2021). Real-time dispatching of air taxis in metropolitan cities using a hybrid simulation goal programming algorithm. Expert Systems with Applications, 178,

Terkaj, W., Tolio, T., and Urgo, M. (2015). A virtual approach for in situ simulation to support production and maintenance planning. CIRP Annals-manufacturing technology, 64, 451-454.

Ulutas, B. and Islier, A.A. (2015). Dynamic facility layout problem in footwear industry. Journal of manufacturing systems, 36, 55-61.

Vanichbuncha, K. (2006). Quantitative Analysis. 8th ed. Bangkok: Chulalongkorn University. (in Thai)

Wang Pan, Michela Turrin, Christian Louter, Sevil Sariyildiz and Yimin Sun (2019). Integrating multi-functional space and long-span structure in the early design stage of indoor sports arenas by using parametric modelling and multi-objective optimization, Journal of Building Engineering, 22, 464-485.