International Journal of Business and Technology Management
e-ISSN: 2682-7646 | Vol.6, No. 3, 537-544, 2024
http://myjms.mohe.gov.my/index.php/ijbtm

Application of Discrete Event Simulation in Modelling a SME Manufacturing System

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Received: 30 August 2024 | Accepted: 25 September 2024 | Published: 1 November 2024

DOI: https://doi.org/10.55057/ijbtm.2024.6.3.48

Abstract: *The utilisation of IR4.0 simulation technology within manufacturing sector to analytically examined, learned and verified through illustration modelling. This research objective is to simulate the production line of a SME helmet manufacturing and assess the efficiency, utilise ARENA software. The research obtained data provided by the organisation and direct observation, of each data process time and standard time in the production line. The painting production line been selected to simulate, whereby engaged in five different processes to produce a singular product helmet type. The ARENA simulation software adopted for model creation, and developed model undergoes verification and validation before the analysis of the simulation results. The analysis simulation results displayed increase in workers utilisation if the restructuring the resources allocation for dust vacuum and quality check point 2. The research is valuable for the company as it focuses on the critical need to improve the efficiency and utilisation of its production lines, which contributing to the overall advancement of the green economy.*

Keywords: Efficiency, Manufacturing, Optimisation, Production Line, Simulation

1. Introduction

Malaysia Micro, Small and Medium Enterprise (MSME) was the backbone of the nation's economy, accounting for 97.4 percent of total establishments and 38.4 percent of the gross domestic product (GDP), in the year 2021. In the same year, the MSME manufacturing industry experienced significant growth to 8.5 percent, reflecting the critical role plays in driving economic growth, fostering innovation, and providing employment opportunities (MIDA, 2022; MITI, 2023). Nevertheless, MSME faces numerous challenges in the highly competitive global market, including limited fund finance access, limited skill technological, and shifting in consumer market needs (MIDA, 2022; MITI, 2023; Abdul et al., 2023a). To address these problems, the government has encouraged the adoption of digital technologies as cutting-edge approaches to optimize the manufacturing production processes (MIDA, 2022; MITI, 2023). In this manner, simulation technology has been identified as an effective tool for modeling, analyzing, and optimizing complicated production systems, allowing MSME to model

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scenarios, identify inefficiencies, and optimize production processes in a digital setting before actual execution (MITI, 2023; Talib et al., 2023). However, the adoption of simulation technology among MSME remains relatively in the early stages due to insufficient knowledge, technical skills, and resource limitations (MITI, 2023; Deif & Mohib, 2020; Ismail et al., 2022). This research aims to fill this gap by performing a case study simulation of a MSME manufacturing company to enhance its production line efficiency. The findings will provide useful insights and recommendations for promoting wider adoption and effective integration of simulation technologies in Malaysian MSME.

2. Literature Review

The Industry Revolution 4.0 (IR4.0) technology is a significant shift in the global manufacturing sector, whereby combining digital technology, data analytics, and automation. This shift presents both opportunities and challenges for MSME, which are vital for economic growth, job creation, and innovation (Abdul et al., 2023a; Ismail et al., 2022; MIDA, 2022; MITI, 2023). IR4.0 is driven by technologies such as Internet of Things (IoT), artificial intelligence (AI), robotics, and big data analytics, which can transform production processes and improve productivity level. Nevertheless, the implementation of IR4.0 technologies in MSME operations requires overcoming challenges such as limited resources, technological skills, and organizational readiness (MIDA, 2022; MITI, 2023). Thus, a comprehensive strategy involving strategic planning, capacity building, and collaboration with stakeholders is required to overcome this issue (MITI, 2023). Strategic planning involves evaluating an organization's current competencies, identifying areas for improvement, and developing a digital transformation plan. Besides, capacity building including training programs and information sharing platforms, is essential for providing the necessary skills and experience to effectively utilize IR4.0 technology (MIDA, 2022; MITI, 2023; Shahzad et al., 2023). Meanwhile, engaging with stakeholders consisting of government agencies, industry groups, and technology providers is crucial for creating a supportive environment for innovation and IR4.0 implementation. Government agencies can offer incentives, regulatory assistance, and financial opportunities to encourage MSME investment in digital technology (Abdul et al., 2023b). Then, industry associations can serve as information hubs, facilitating networking opportunities and sharing best practices among MSME companies (MIDA, 2022; MITI, 2023).

MSME operating in the manufacturing sector are facing significant pressure to improve their production processes to remain competitive and respond to evolving market demands. The implementation of simulation technology is a crucial strategy for MSME to enhance the efficiency of their production lines and achieve sustainable growth (MIDA, 2022; MITI, 2023). The simulation technology allows for the creation of virtual models that accurately replicate real-world industrial processes, whereby MSME has the capability to assess several production scenarios to gain a deep understanding of their operations, find areas of inefficiency, and uncover chances for optimisation. Besides, simulation can utilise data-driven analysis to make informed decisions, rather than relying solely on intuition or trial-and-error approaches (Li et al., 2022). Furthermore, simulation technology is helpful since it enables experimentation without risk involve. MSME can employ simulations to assess various scenarios for feasibility and potential consequences, instead of implementing changes directly into the production line. This approach avoids disruptions to operations and the related expenses (Raja et al., 2023). Simulation also enables the opportunity to explore several scenarios, evaluate their effectiveness, and determine the most efficient solutions before putting them into practice. It facilitates the ability to make well-informed decisions, mitigate risks, and avoid costly errors (MIDA, 2022; Attaran et al., 2023). Production processes are subject to constant change and

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can be influenced by several factors such as market demand, technological advancements, and the availability of resources (Ismail et al., 2022). Simulation technology provides a platform for monitoring production performance, analysing patterns, and identifying opportunities for improvement over time. Therefore, MSME can increase their operational efficiency by including simulation techniques in their ongoing efforts to better performance. This approach allows them to discover new opportunities and continually optimise their operations (Deif & Mohib, 2020; Attaran et al., 2023).

3. Methodology

This research used a case study methodology to examine a production painting workstation system in a specific manufacturing facility, with the aim of comprehending its functions in a specific setting. Bell and colleagues (2011) provide a concise definition of a case study as a comprehensive and meticulous analysis of a single instance. This research carefully follows the phases of discrete event simulation (DES) simulation to achieve more accurate results. Robert E. Shannon (1998) proposed a 12 phases process for conducting a simulation. These phases include problem definition, project planning, system definition, conceptual model formulation, preliminary experimental design, input data preparation, model translation, verification and validation, final experimental design, experimentation, analysis and interpretation, and implementation and documentation. On another hand, Anu Maria (1997) conducted a comprehensive study on simulation and presented a schematic diagram (Figure 1) along with 11 phases for developing an experimental simulation model. These phases include identifying the problem, formulating the problem, collecting and processing real system data, formulating and developing a model, validating the model, documenting the model for future use, selecting an appropriate experimental design, establishing experimental conditions for runs, performing simulation runs, interpreting and presenting results, and recommending further actions.

This study followed the suggested phases for conducting a proper simulation modelling process. The first stage involved problem identification, which established the objectives and rationale behind investigating a specific subject. The second stage was system definition, which defined parameters and restrictions such as logical sub-systems, entities, resources, and basic flow patterns of entities. The third stage was conceptual model formulation, which involved constructing an initial model that provided a clear delineation of elements, descriptive variables, and logical interactions. The fourth stage involved real system data collection and processing, from part arrival to the main assembly stage. The data was collected within the month of March to April 2024, to obtain 1500 dataset. Data collection utilities templates for data collectors to record each process processing time. The fifth stage involved model formulation and development, using ARENA simulation software to construct a model of the system and its alteration. The model was updated through cycle time data and additional factors obtained from interviews, including error rates, rework durations, and product order sequences. The sixth stage involved model verification and validation, where employees evaluated the model's functionality and tested it to ensure its reliability and accuracy. The verification demonstrated that the computer program functioned according to its planned and expected behavior (Figure 1), and validation focused on the extent to which the model's behavior accurately reflected the real-world system under simulation. The seventh stage involved experiment design and run, developing a systematic approach to carry out an experiment that yielded desired data and outlining the steps for each specific test run in the experimental design. The simulation was performed to generate necessary data and conduct a sensitivity analysis.

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Finally, the study involved analysis and interpretation, drawing inferences from the data produced through the simulation experiments.

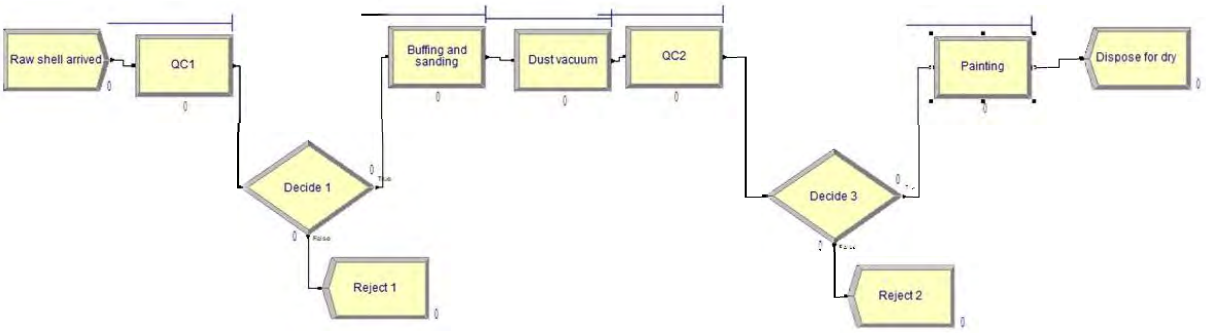


Figure 1: Model of the painting workstation

The simulation data expression obtained and was then analysed by Arena Input Analyser. All the inter-arrived times were analysed to determine a summary of sample statistics with the best fit distribution for each data set (Table 1).

Table 1: Data expression

Name	Total resource	Expression
Raw shell arrived (minutes)		EXPO(5)
Quality check 1 (minutes)	1	2 + LOGN(3.03, 1.44)
Buffing and sanding (minutes)	2	2 + 17 * BETA(9.18, 16.3)
Dust vacuum (minutes)	1	NORM(4.63, 1.24)
Quality check 2 (minutes)	1	2 + ERLA(0.602, 5)
Painting (minutes)	2	4 + LOGN(6.96, 2.45)

4. Results and Discussion

Figure 2 shows the successful operation of the simulation model and verifies its absence of logical errors. Table 2 displays the comparison between actual data and the simulation model. Given the confidence that the outcomes are below 10%, researchers conclude that the model is valid, allowing for the further alternative models progress.

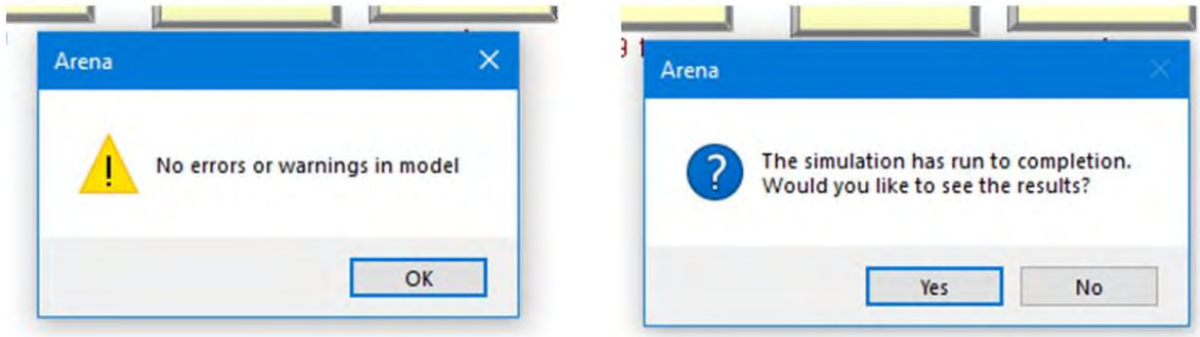


Figure 2: Snapshot of verification method in ARENA software in the painting workstation

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Table 2: Worker utilisation at various processes

Process	Simulation output (minutes)	Actual data (minutes)	Difference (%)
Quality check 1	4.9567	5.0291	-1.44%
Buffing and sanding	8.3002	8.1987	1.24%
Dust vacuum	4.6853	4.6278	1.24%
Quality check 2	4.8019	5.0105	-4.16%
Painting	10.967	10.9257	0.39%

From the simulation model, the current simulation models' findings for staff utilisation rates (Table 3). Most of the ulitisation rate of the worker is very high (more than 90%), shows a possible bottleneck situation. The two workstations consisting of dust vacuum and quality check point 2 are also not fully utilized (less than 60%). These results of worker utilisation might be one of the painting system weaknesses.

Table 3: Worker utilisation at various processes in painting system

Process	Average worker utilisation (%)
Quality check 1	98.023%
Buffing and sanding	99.633%
Dust vacuum	55.975%
Quality check 2	57.059%
Painting	97.742%

Each process average waiting time and processing times are displayed in Table 4. Based on the results, the bottleneck in the painting system is detected in the buffing and sanding, as well as the painting process itself. The raw helmet needs to wait more than two hours, even though the allocation of two workers for both processes. The long waiting time might be due to long processing time, in which 8.3002 minutes and 10.967 minutes respectively. For buffing and sanding, the processing time is in between 4.8848 and 12.686 minutes. On another hand, the painting, the processing time is in between 6.8093 and 22.194 minutes.

Table 4: Simulation results about the processing time for all processes

Process	Average waiting time per process (minutes)	Average value-added processing time per process (minutes)
Quality check 1	38.995	4.9567
Buffing and sanding	214.86	8.3002
Dust vacuum	0.02592	4.6853
Quality check 2	0.21134	4.8019
Painting	124.95	10.967
Total	309.41	33.176

Based on the observed finding, the manufacturing painting system is given a suggested improvement model to increase resource ultilisation rates by reallocating workers to the relevant processes. After, the suggested improvement model outcomes are compared to the original current model. The main suggested is the combination of dust vacuum and quality check point 2 (Figure 3). The assumption of the suggested combine resources and combination both duration process time, and using Poisson distribution, value of POIS (9.6382).

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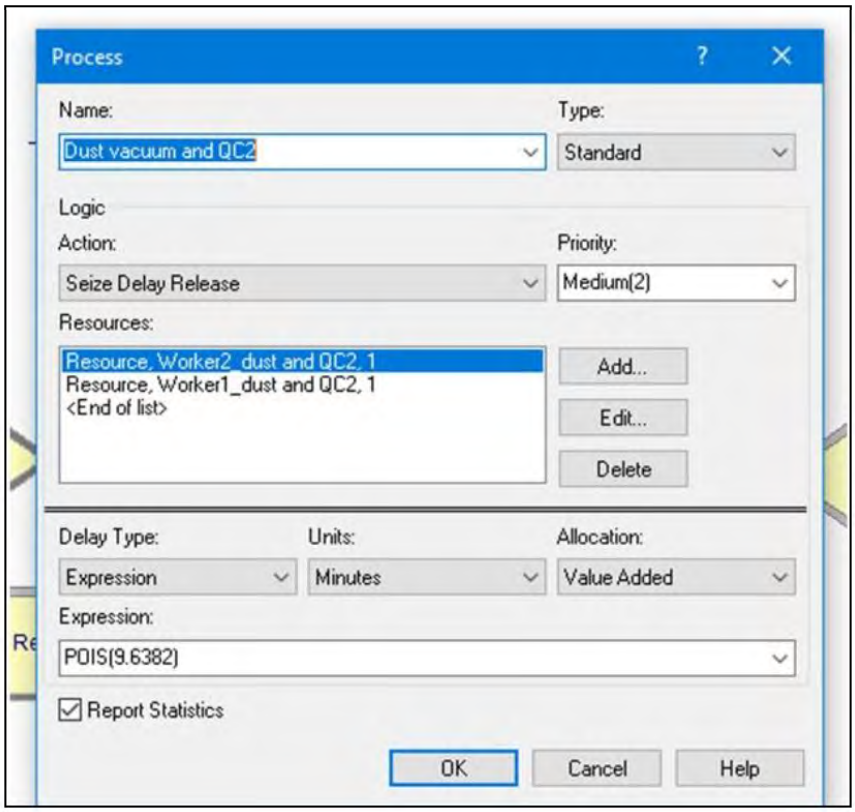


Figure 3: Snapshot of combining process module and resource capacity

The simulation model given in the research enabled the manufacturing helmet to better comprehend their current painting system. The suggested improvement is designed to evaluate potential improvements to the current painting system, which can be made using existing resources capacity. The simulation model results support workers utilization rates of more than 80 percent (Table 5). Besides, the waiting time for entity also reduce significantly. With the setup setting of entity painting out of 105 pieces, the current model ended at the time 1178.2019 minutes. However, the improvement model reduces to 1121.5476 minutes. The number entity in the system reduces from 233 pieces to 192 pieces. However, the number entity out from the system increases from 109 pieces to 113 pieces.

Table 5: The comparisons of the current and improved models

Identifier	Process	Current model	Improvement model (Combine 2 workers for dust vacuum and QC2)
Average worker utilisation (%)	Quality check 1	98.023%	86.421%
	Buffing and sanding	99.633%	99.614%
	Dust vacuum	55.975%	98.966%
	Quality check 2	57.059%	-
	Painting	97.742%	96.848%
Average waiting time per process (minutes)	Quality check 1	38.995	13.235
	Buffing and sanding	214.86	131.72
	Dust vacuum	0.02592	81.894
	Quality check 2	0.21134	-
	Painting	124.95	22.502
	Total	309.41	
Average value-added processing time per process (minutes)	Quality check 1	4.9567	5.0932
	Buffing and sanding	8.3002	8.3120
	Dust vacuum	4.6853	9.4444
	Quality check 2	4.8019	-
	Painting	10.967	10.344
	Total	33.176	31.533

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5. Conclusion

The objective of this study is to simulate the production line of a SME helmet manufacturing and assess the efficiency. The study adopted ARENA software to simulate the current model and improvement model. The improvement simulation model results support workers utilization rates more than 80 percent. Besides, the waiting time for entity also reduce significantly. This study directly contributes to theory, practicality and policy. For theory, by creating virtual models of manufacturing painting systems, simulation evaluates the impact of increased connectivity and interoperability between cyber-physical systems. For practical, the modelling and optimising production schedules, materials flows, and recourse utilisation within painting system to enhance efficiency and responsiveness. For policy, it is a call to authorities to consider implementing policies and funding programs to encourage MSME to invest in simulation capabilities. Finally, the study is valuable for the organisation as it concentrations to improve the efficiency and utilisation of its production lines, whereby contribute to the overall advancement of the green economy. However, the study is only limited to the painting system in the manufacturing operation, hence more systems should be inserted for future to get clearer picture of the whole manufacturing system. Besides, it is also encouraged to gather more data to observe the process flow.

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