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Supply chain performance analysis using discrete system simulation method: A case study in a furniture company

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ABSTRACT

As time progresses, the evolving industrial world demands that companies devise the best strategies to achieve their desired goals. A well-designed system is expected to increase the profitability of the company itself. CSD is an interior furniture and interior design studio located in the city of Cilegon, Banten. The challenge faced by CSD is the inability to meet order deadlines during periods of high demand. The objective of this study is to assess the level of machine utility within the existing process and provide recommendations to achieve an optimal process. The methodology employed includes system simulation and model development using Promodel software. Additionally, statistical tests, model validation, and ANOVA tests were conducted. Based on the results, it was determined that the level of machine utility at CSD is 17.48% for shaping planning, 30.08% for grinding, 14.88% for assembly, and 29.98% for finishing. The proposed solution, scenario or proposal 2, suggests combining the assembly and finishing workstations, resulting in increased machine utility.

1. Introduction

The inventory management system is a combination of technology (hardware and software) and procedures used to monitor and maintain the goods stored in a company. These items can include company assets, raw materials, or finished products ready for delivery to vendors or end consumers [1]. It is essential for every company to have an effective and efficient system in place to expedite operational processes.

The primary objective of the system is to increase profits for the company itself. However, during the preparation of an actual system, there are several risks to consider, such as high costs, potential hazards, or the risk of damage to the system itself. Simulation serves as a method for presenting learning experiences by utilizing imitation situations to understand certain concepts, principles, or skills. Simulation can be employed as a teaching method with the assumption that not all learning processes can be carried out directly on actual objects [2]. Promodel is a supporting software that can be utilized in simulations. During the model development process, various tests are required, including statistical tests, model validation, and ANOVA tests.

CSD is an interior furniture and interior design studio located in the city of Cilegon, Banten. The challenge faced by CSD is the inability to complete orders on time during periods of high demand. To address these issues, the author intends to conduct research on the production process at each workstation to assess the machine's utility. By determining the level of machine utility, it is hoped that workers can further optimize production time, enabling them to fulfill customer requests more quickly and efficiently.

2. Material and method

This research was conducted on the production system at CSD, which is located in Cilegon, Banten. The company specializes in producing various types of furniture, with a specific focus on one of its products, namely ledge products. The research was carried out over a period of two weeks through the process of observing and interviewing the business owners and their workers.

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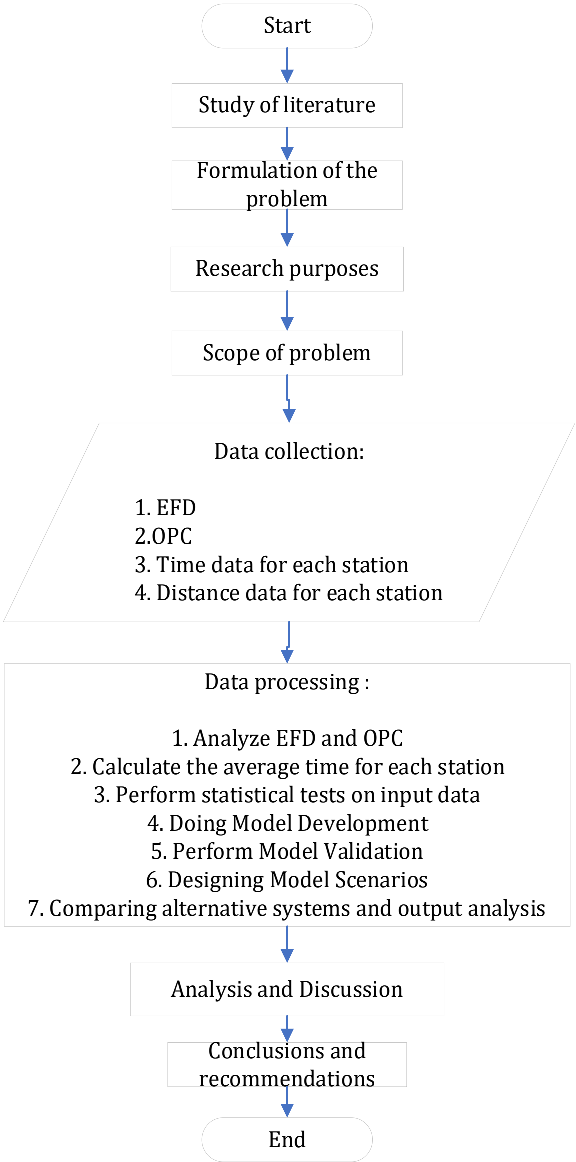

Figure 1. Research flowchart

2.1. Flowchart

Based on the flowchart shown in Fig. 1, it is evident that this research was conducted by following a series of steps, starting with problem formulation, objective setting, and establishing limitations. The data collection process involved gathering production time data for each workstation, creating entity flow diagrams, and developing operation process charts. Subsequently, the collected data was processed through statistical tests and simulations [3]. An analysis was then performed, leading to the formulation of suggestions that were subsequently tested using the ANOVA test. Once the best proposal was identified, it can be concluded that the research phase was complete [4].

2.2. Data collection

The following data has been collected and obtained to support the ongoing research. Specifically, for this study, the data collected is related to the production time at each station in CSD. The time data for each station is presented in Table 1.

Table 1.
Processing time for each workstation

No	Station				Prod. time (s)
	1	2	3	4	
1	55	121	56	122	369
2	58	110	64	112	374
3	60	117	58	127	389
4	57	116	58	120	381
5	58	110	61	112	365
6	55	129	55	122	375
7	59	115	65	115	375
8	61	124	59	123	397
9	63	127	64	119	397
10	63	120	63	127	394
11	58	129	60	111	368
12	63	125	58	110	366
13	57	112	64	116	370
14	61	122	62	113	369
15	58	110	55	113	348
16	58	127	65	128	402
17	65	124	63	117	386
18	59	130	65	119	398
19	63	110	56	120	376
20	56	130	56	122	393
21	62	110	57	112	358
22	56	126	59	114	382
23	64	123	64	116	397
24	64	123	60	113	377
25	62	130	59	115	384
26	62	119	59	113	382
27	56	123	59	125	387
28	60	119	60	124	381
29	56	115	55	117	358
30	61	126	55	123	379

Note:
1 (Shapping & Planning), 2 (Grinding), 3 (Assembly), 4 (Finishing)

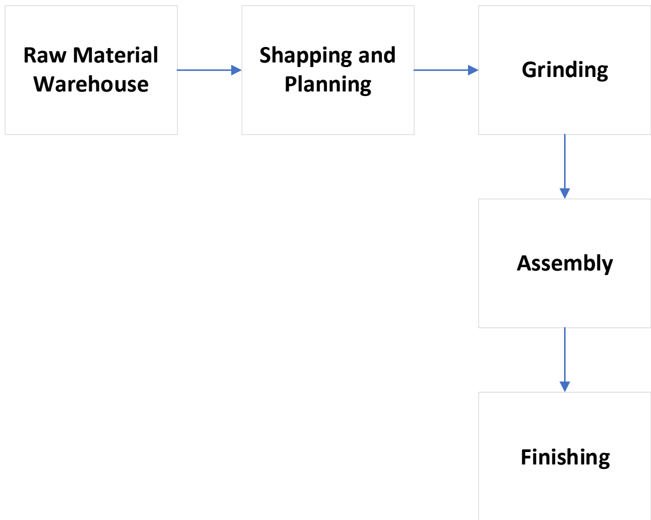

Figure 2. Entitiy Flow Diagram

Based on the provided Table 1, it is evident that there are 30 data points for each station. The shaping & planning stations have a time range of 55-65 seconds, the grinding stations have a time range of 110-130 seconds, the assembly stations have a time range of 55-65 seconds, and the finishing stations have a time range of 110-128 seconds. Furthermore, the total production time ranges between 348-402 seconds, which is equivalent to 5.8-6.7 minutes.

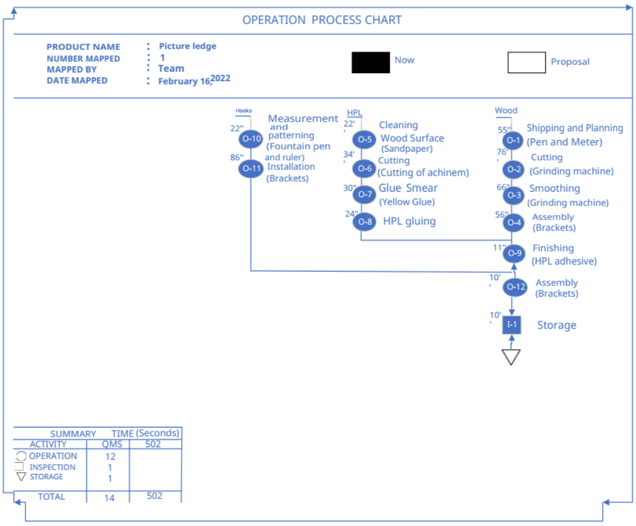

Figure 3. Operation Process Chart

Table 2.
Processing time for each workstation

Desciption	Station			
	1	2	3	4
longest time (s)	65	130	65	128
fastest time (s)	55	110	55	110
average (s)	59.67	120.73	59.8	118
stdev	2.99	6.81	3.39	5.32
variance	8.92	46.41	11.54	28.28

Note:
1 (Shapping & Planning), 2 (Grinding), 3 (Assembly), 4 (Finishing)

2.3. Entity Flow Diagram

The entity flow diagram for the packaging process at CSD is presented in Fig. 2. From the diagram, it is observed that the production process of furniture products at CSD begins with the retrieval of raw materials from the storage warehouse. The raw material, in this case, is plywood. Subsequently, the plywood is cut into the desired size and shape using a grinding machine. Afterward, the cut pieces are assembled to form the final product. The last stage in the process is finishing.

2.4. Statistical test

The descriptive statistics results for the shaping and planning stations, obtained using the Pro Model software, are presented in Table 2 [5]. Table 2 presents the results of a descriptive statistical test on the product completion time data at each station, measured in seconds. Based on the table, it can be observed that the highest value or longest time to complete the product is 130 seconds at the Grinding Station, while the fastest time to complete the product is 55 seconds at the Shaping & Planning and Assembly Stations. Furthermore, the highest average completion time is 120.73 seconds at the Grinding Station, and it exhibits the highest standard deviation value of 6.8124 seconds among all the stations. Additionally, the collected time data reveals a highest variance value of 46.4092 at the Finishing Station.

Table 3.
Data adequacy test

Workstation	*N*	*N'*	Remark
1	30	3.875	Sufficient
2	30	4.924	Sufficient
3	30	4.993	Sufficient
4	30	3.140	Sufficient

Note:
1 (Shapping & Planning), 2 (Grinding), 3 (Assembly), 4 (Finishing)

Table 4.
Statistical test results

Workstation	Test			
	a	b	c	d
1	Uncorelated	*	DNR	DNR
2	Uncorelated	*	DNR	DNR
3	Uncorelated	*	DNR	DNR
4	Uncorelated	*	DNR	DNR

Note:
1 (Shapping & Planning), 2 (Grinding), 3 (Assembly), 4 (Finishing),
a (correlation test), b (scatter plot), c (run test), d (goodnes of fit test)
* The data is scattered randomly. Unrelated data (independent)
DNR: Do Not Reject

Table 5.
Data distribution test

Workstation	Distribution	Rank	Mean	Sigma
1	Uniform	100	59.67	2.89
2	Uniform	49.6	120.73	6.81
3	Uniform	100	59.8	3.397
4	Lognormal	100	118	5.32

Note:
1 (Shapping & Planning), 2 (Grinding), 3 (Assembly), 4 (Finishing)

The next step is the data adequacy test [6]. Referring to Table 3, it can be observed that there are 30 data points collected at each workstation, based on 30 days of production. Calculating *N*', it is determined that the sample size at each workstation is smaller than the required sample size, resulting in $N > N'$. Therefore, it can be concluded that the data collected from each workstation is sufficient for use in the next stage of the analysis.

The following are the results of statistical tests and parameter estimates that have been obtained [7]. Table 4 presents the results of statistical tests and parameter estimates for each workstation. According to the correlation test in the table, there is no significant correlation, and the scatter plot indicates that the data is randomly distributed [8].

The results of the run test and goodness of fit indicate that the data is accepted. In Table 5, which displays the parameter estimation, it can be observed that the distribution for each workstation is mostly uniform, except for the finishing station, which follows a lognormal distribution. This conclusion is based on the highest distribution rank obtained from the test results [9].

3. Results and discussions

3.1. Existing model

CSD manufactures a large quantity of standardized shelves to be stored in the warehouse. The wooden materials are the entities being processed, and the processing time for shaping & planning machines follows a normal distribution with an average of 60 seconds and a standard deviation of 5 seconds. Similarly, the grinding machines exhibit a normal distribution with an average processing time of 120 seconds and a standard deviation of 10 seconds. The assembly machines also follow a normal distribution with an average processing time of 60 seconds and a standard deviation of 5 seconds. Finally, the finishing machines demonstrate a normal distribution with an average processing time of 120 seconds and a standard deviation of 10 seconds. The arrival rates of the products are exponentially distributed with an average of 420 seconds. The movement of products, from arrival to different machines and until their departure, is facilitated by human labor. The distances between the stations can be seen in Table A1 (see Appendices) [10].

Therefore, the simulation results obtained from the scenarios using Pro-Model software are presented below. Fig. 4 illustrates the simulation model utilized in Pro-Model software, depicting the actual production activities at CSD. From this model, data regarding locations and entity results are obtained, as shown in Table A2 (see Appendices) [11]. The table presents machine utility data for each station: shaping planning at 17.48%, grinding at 30.08%, assembly at 14.88%, and finishing at 29.98%.

Table 6 presents entity activity data results. Based on Table 6, the data obtained for product results over an 8-hour period is as follows: 71 products have been processed, while 1 product is still pending. The average time in the system is 6.3 seconds, the average operating time is 6.04 seconds, and the average downtime is 0.25 seconds [12].

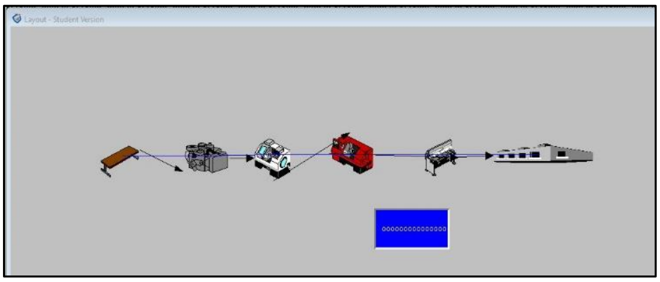

Figure 4. Simulation model of CSD

Table 6.
Entity activity data results

No	Activity	Value
1	Total Exits	71,00
2	Current Quantity In System	1,00
3	Average Time In System (min)	6,30
4	Average Time In Move Logic (min)	0,00
5	Average Time Waiting (min)	0,00
6	Average Time In Operation (min)	6,04
7	Average Time Blocked (min)	0,25

3.2. Paired sample t-test

In the paired test, the data results obtained using paired samples statistics and paired samples correlations are as follows [13]. Referring to Table A3 (see Appendices), it can be observed that the significance value is 0.362, which is greater than 0.1. Therefore, H_0 is accepted, and H_1 is rejected, indicating no significant difference. This implies that the real system results are like the simulation results. With a confidence level of 95%, the Thit value is 0.959 with df 9. For Ttable (ta/2, n-1), it is 2.262. Thus, it can be concluded that Thit < Ttable, indicating that H_0 is accepted. Therefore, there is no significant difference between the real system and the simulation results that were generated.

3.3. Best scenario

Based on the Figure 5, the simulations conducted using the Pro-Model software resulted in the identification of the best proposal, which is alternative 2 [14]. In this optimal scenario, a merger was implemented at two stations, resulting in the creation of a new station that combines assembly and finishing processes. This merger enables CSD to save space in its production facilities and increase utility. The data obtained from this simulation are presented in Table A4 (see Appendices) [15].

3.4. ANOVA test

The following presents the results of the ANOVA test calculation conducted on the available data and three proposed scenarios. Referring to Table A5 (see Appendices), it can be observed that the *F* value is 40.162, which is greater than the *F* table of 2.87. Therefore, H_0 is rejected, and H_1 is accepted, indicating that there is at least one difference between the existing model and the proposed scenario models. This is further supported by the significance value or *p*-value of 0.000 [16].

Table A5 (see Appendices) shows the multiple comparisons between existing condition and scenarios. Based on Table A5, the results of the ANOVA test processing reveal three scenarios: scenario 1, scenario 2, and scenario 3. Scenario 1 involves minimizing the distance by reducing the displacement between stations by 0.5 meters compared to the existing layout. Scenario 2 combines the assembly and finishing workstations into a single station. Scenario 3 focuses on minimizing the moving distances from scenario 2. Among these scenarios, the largest mean difference is observed in scenario 2. Consequently, it can be concluded that the best scenario is scenario 2, or proposal 2 [17].

4. Conclusions

Based on the results that have been obtained, the following conclusions have been reached. The level of machine utility found in CSD is shaping planning at 17.48%, grinding at 30.08%, assembly at 14.88%, and finishing at 29.98%. The best proposal used is scenario or proposal 2 with the largest mean difference. This proposal involved combining assembly and finishing workstations into one. Machine utility has also increased. The machine utility percentages are as follows: shaping planning is 20.23%, cutting is 32.55%, and assembly and finishing is 42.62%.

Declaration statement

Dyah Lintang Trenggonowati: **Conceptualization, Methodology, Supervision**. Maria Ulfah, Asep Ridwan, Achmad Bahauddin: **Software, Writing-Original Draft**. Ratna Ekawati: **Conceptualization, Resources.** Aditya Rahadian Fachrur: **Writing - Review & Editing.** Yayan Harry Yadi: **Data curation**. Ani Umyati, Atia Sonda: **Resources, Validation**, **Writing - Review & Editing.**

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Disclosure statement

The authors report there are no competing interests to declare.

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Data availability statement

The authors confirm that the data supporting the findings of this study are available within the article or its supplementary materials.

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Appendices

Table A1.
Simulation model distance data

From	To	Distance (meters)
Warehouse	Shaping & Planning	2
Shaping & Planning	Grinding	1
Grinding	Splicing / Assembly	1
Splicing / Assembly	Finishing Machine	1
Finishing Machine	Warehouse	2

Table A2.
Locations data results

Name	Schedule Time	Capacity	Total Entries	Utilization (%)
Raw Material Warehouse	8,00	9999999,00	72,00	0,00
Shaping Planning	8,00	1,00	72,00	17,48
Grinding	8,00	1,00	72,00	30,08
Assembly	8,00	1,00	71,00	14,88
Finishing	8,00	1,00	71,00	29,98
Finished Product Warehouse	8,00	1,00	71,00	0,00

Table A3.
Paired samples test

				Pair 1
				Real System- Simulation
Paired Samples Test	Paired Differences		Mean	0,058
			Std. Deviation	0,191
			Std. Error Mean	0,060
		95% Confidence Interval of the Difference	Lower	-0,079
			Upper	0,195
			t	0,959
			df	9
			Sig. (2-tailed)	0,362

Table A4.
Best scenario simulation results

Name	Schedule Time	Capacity	Total Entries	Utilization (%)
Raw Material Warehouse	2,10	9999999,00	18,00	0,00
Loc 1	2,10	1,00	0,00	0,00
Shaping Planning	2,10	1,00	18,00	20,43
Loc 2	2,10	1,00	0,00	0,00
Cutting	2,10	1,00	18,00	32,55
Loc 3	2,10	1,00	0,00	0,00
Assembly Finishing	2,10	1,00	18,00	42,62
Loc 4	2,10	1,00	0,00	0,00
Finished Product Warehouse	2,10	1,00	18,00	0,00
Loc 5	2,10	1,00	0,00	0,00

Table A5.
ANOVA test calculation results

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	7,050	3	2,350	40,162	0,000
Within Groups	2,107	36	0,059		
Total	9,157	39			