DYNAMIC SYSTEM SIMULATION TO IMPROVE SUPPLY CHAIN PERFORMANCE IN FOOD AND BAVERAGE COMPANIES

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ABSTRAK

Dalam menghadapi persaingan bisnis yang semakin kompetitif, perusahaan food and beverage dituntut unruk meningkatkan efisiensi produksi dan menjaga ketahanan rantai pasok guna mencapai target produksi secara optimal. Penelitian ini dilakukan untuk mengidentifikasi faktor penyebab ketidaksesuaian antara target dan hasil produksi aktual, menyevaluasi kinerja rantai pasok, serta mensimulasikan skenario perbaikan menggunakan sistem dinamis. Pendekatan Supply Chain Operation Reference (SCOR) digunakan sebagai kerangka kerja dalam menganalisis dan mengidentifikasi titik kritis dalam rantai pasok. Selanjutnya, pengukuran kinerja dilakukan dengan metode Snorm De Boer untuk menilai performa dan menentukan indikator yang memerlukan perbaikan. Simulasi skenario dilakukan menggunakan Powersim Studio 10 untuk menguji pengaruh berbagai variabel. Berdasarkan hasil simulasi dan pengujian statistik ANOVA, didapatkan skenario terbaik untuk menurunkan product defect from production line adalah skenario 3 dan skenario terbaik untuk menurunkan downtime SBL adalah skenario 2. Dan apabila ditinjau secara keseluruhan, skenario 5 merupakan skenario yang paling seimbang karena mampu menurunkan downtime SBL sebesar 1,82% dan mengurangi product defect from production line sebesar 1,19%, sehingga memberikan dampak positif secara seimbang terhadap efisiensi operasional dan kualitas produksi. Penelitian ini diharapkan dapat menjadi acuan dalam pengambilan keputusan strategis perusahaan serta pengembangan metode evaluasi rantai pasok di masa mendatang.

Kata kunci: *F and B, SCM, KPI, SCOR, Snorm De Boer, Sistem Dinamis*

ABSTRACT

In facing increasingly competitive business competition, food and beverage companies are required to improve production efficiency and maintain supply chain resilience in order to achieve optimal production targets. This study was conducted to identify the factors causing the discrepancy between targets and actual production results, evaluate supply chain performance, and simulate improvement scenarios using dynamic systems. The Supply Chain Operation Reference (SCOR) approach is used as a framework in analyzing and identifying critical points in the supply chain. Furthermore, performance measurement is carried out using the Snorm De Boer method to assess performance and determine indicators that require improvement. Scenario simulations were carried out using Powersim Studio 10 to test the influence of various variables. Based on the results of the simulation and ANOVA statistical testing, the best scenario for reducing product defects from the production line is scenario 3 and the best scenario for reducing SBL downtime is scenario 2. And when viewed as a whole, scenario 5 is the most balanced scenario because it is able to reduce SBL downtime by 1.82% and reduce product defects from the production line by 1.19%, thus providing a positive impact in a balanced way on operational efficiency and production quality. This research is expected to be a reference in making strategic company decisions and developing supply chain evaluation methods in the future.

Keywords: *F and B, SCM, KPI, SCOR, Snorm De Boer, Dynamic System*

INTRODUCTION

In an era of increasingly tight business competition, companies are required to continue to innovate and improve the quality and efficiency of production in order to win the competition in the market, one of the keys to success in facing these challenges is to continue to prioritize customer satisfaction, while maintaining profitability and operational efficiency. For this reason, companies need to improve performance in various aspects, one of which is supply chain management. Effective supply chain management allows company operations to run smoothly and efficiently [1].

One of the food and beverage companies studied is currently facing challenges in achieving production targets on one of its production lines. There is a mismatch between the production targets that have been set and the actual results obtained. This has the potential to cause negative impacts such as decreased productivity and disruption to the resilience and efficiency of the company's supply chain.

This problem indicates a gap in supply chain management that needs to be further analyzed. Given that the supply chain plays an important role in the company, facilitating the flow of products from raw materials to finished goods sent to consumers. Therefore, it is important for companies to measure supply chain performance to assess how effectively the supply chain operates [2]. So companies need to measure and analyze supply chain performance as a whole to identify the root of the problem and design the right improvement strategy.

In this study, the Supply Chain Operations Reference (SCOR) approach is used to systematically evaluate and analyze supply chain performance. The SCOR model helps companies map supply chain processes, identify critical points, and develop more targeted improvement plans. Then, performance measurements are carried out using the Snorm De Boer method to assess the level of achievement of each indicator. System analysis is carried out through a dynamic system approach using powersim software, through the development of causal loop diagrams and stock flow diagrams to simulate the relationship between variables and flows in the system. Simulations are run in business as usual (BAU) scenarios and several scenarios. The simulation results are then analyzed using the ANOVA test to determine significant differences between scenarios, followed by a post hoc test to identify the best scenario based on comparisons between groups.

Through this approach, it is hoped that companies can gain a deeper understanding of the problems they face and formulate more appropriate solutions to increase production efficiency and overall supply chain resilience.

RESEARCH METHODS

This study uses qualitative and quantitative approaches with dynamic system modeling methods to analyze and simulate the supply chain process in a food and beverage company. Modeling is based on the Supply Chain Operations Reference (SCOR) framework to map processes, identify critical points, and formulate improvement strategies. Performance measurement is carried out using the Snorm De Boer method to assess indicator achievement and determine improvement priorities. System simulation is carried out using Powersim software by building causal loop diagrams and stock-flow diagrams. The scenarios run include Business As Usual (BAU) and several other intervention scenarios. The simulation results are analyzed using ANOVA and post hoc tests to identify significant differences between scenarios and determine the best scenario. The following is a flowchart of the research methodology which can be seen in Figure 1.

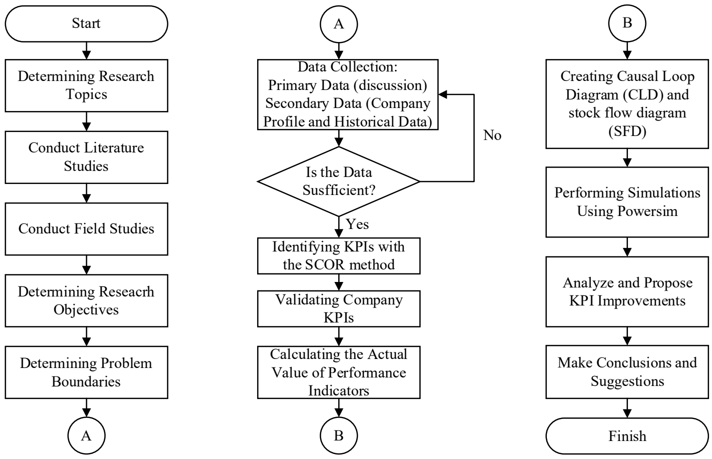

Figure 1. Research Methodology

RESULTS AND DISCUSSION

Supply Chain Process

Supply Chain Management (SCM) is a strategic approach designed to integrate different functions and processes within a company while coordinating with suppliers and customers. SCM involves the seamless flow of materials, products, and information [3]. It covers everything from product development, sourcing, production, logistics, and the information systems necessary to coordinate these activities. The primary goal of SCM is to minimize costs, enhance productivity, and improve customer satisfaction [4]. The following is the supply chain process at company which can be seen in Figure 2.

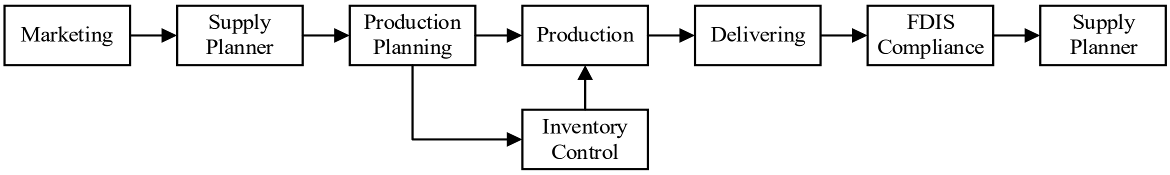

Figure 2. Supply Chain Process

Design of Performance Indicators

Key Performance Indicators (KPIs) are measurable figures used to determine how effectively a person, team, organization, or project is progressing toward specific goals. They are a vital component of performance management, helping to track whether the intended results are being achieved [5].

Supply Chain Operations Reference (SCOR) is a performance measurement model in the supply chain that can describe a company's supply chain in detail through measurement indicators that are appropriate to the company's needs [6]. The SCOR model contains five main processes, namely Plan (Planning Process), Source (Procurement Process), Make (Production Process), Deliver (Delivery Process), and Return (Return Process) [7, 8].

The design of performance indicators was obtained from the results of discussions and adapted to company conditions so that a supply chain hierarchical structure was formed. The following is the supply chain hierarchy at company which can be seen in Figure 3.

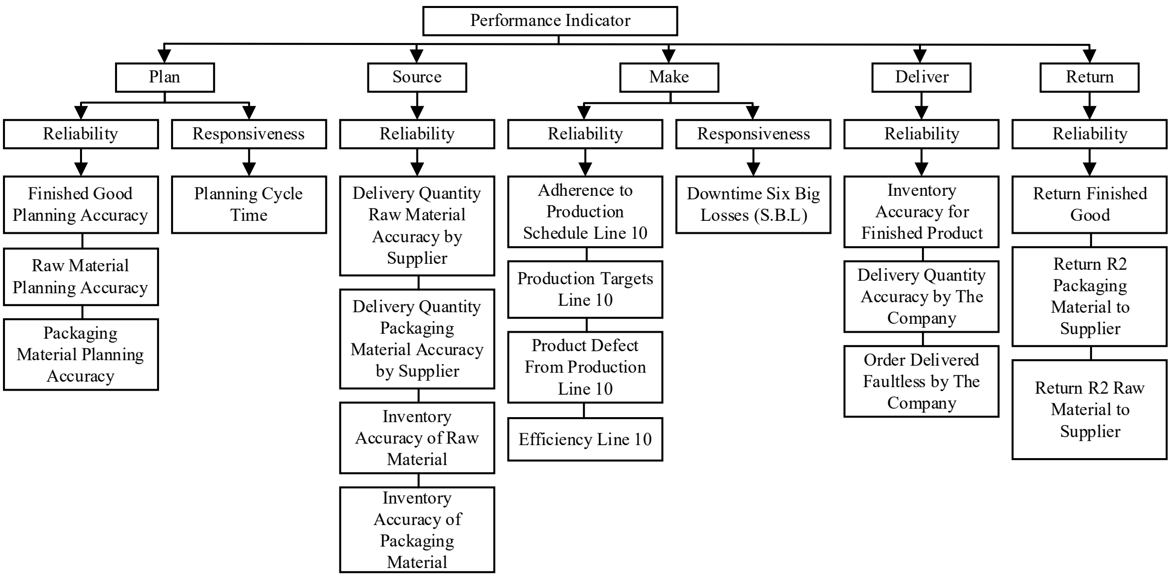

Figure 3. Performance Indicators

In figure 2, there are 4 levels of performance indicator validation. The following are 4 levels of performance indicator validation which can be seen in Table 1.

Table 1. Levels on Performance Indicators

Level	Description
First	The main purpose of conducting Supply Chain Management performance measurement
Second	5 SCOR components consisting of *Plan*, S*ource*, *Make*, *Deliver*, and *Return*
Third	2 attributes in the SCOR method, namely *Reliability* and *responsiveness*
Fourth	Performance indicators that have been adjusted to company conditions

Snorm De boer

Each indicator carries a different weight and is measured on a different scale. As a result, it is essential to standardize the parameters through normalization. This step is crucial in determining the final performance measurement value. The normalization process is carried out using the Snorm De Boer normalization formula, which is as follows [8]:

$$Snorm\ de\ boer = \frac{(Si - Smin)}{(Smax - Smin)} \times 100 \quad (1)$$

Where,

Si = Indicator actual achieved

Smin = The value of achieving the worst performance of the performance indicators

Smax = Best performance achievement value of performance indicators

In this evaluation, the weight of each indicator is transformed into a value range between 0 and 100, where zero (0) represents the lowest or worst performance, and one hundred (100) indicates the best. This ensures that all indicator parameters are standardized, allowing for meaningful analysis of the results. The following are the performance indicators monitors which can be seen in Table 2 [8, 9].

Table 2. Monitor Performance Indicators [8, 9]

Monitoring System	Work Indicators
< 40	Poor
40 – 50	Marginal
50 – 70	Average
70 – 90	Good
> 90	Excelent

The Table 2 clearly represents the value of each performance indicator, making it easy to quickly view the results and immediately understand the condition of each indicator [9]. The results of the Snorm De Boer Normalization can be seen in Table 3.

Table 3. Snorm De Boer

No	Process	Performance Indicators	Average	Smin	Smax	Final Score
1	Plan	Finished Good Planning Accuracy	89,38	0	100	89,38
2		Raw Material Planning Accuracy	100,48	0	110	91,34
3		Packaging Material Planning Accuracy	86,80	0	100	86,80
4		Planning Cycle Time	4	1	4	100,00
5	Source	Delivery quantity raw material accuracy by supplier	100,00	0	100	100,00
6		Delivery quantity packaging material accuracy by supplier	100,00	0	100	100,00
7		Inventory Accuracy of Raw Material	100,00	0	100	100,00
8		Inventory Accuracy of Packaging Material	100,00	0	100	100,00
9	Make	Adherence to Production Schedule	100,00	0	100	100,00
10		Achievement Production Line	82,42	0	100	82,42
11		Product Defect From Production	5,32	100	0	94,68
12		Efficiency Line	94,21	0	100	94,21
13		Downtime Six Big Losses (SBL)	17,57	100	0	82,43
14	Deliver	Inventory Accuracy for Finished Product	95,05	0	100	95,05
15		Delivery Quantity Accuracy by The Company	100,00	0	100	100,00
16		Order Delivered Faultless by The Company	100,00	0	100	100,00
17	Return	Return Finished Good	0,00	100	0	100,00
18		Return R2 Packaging Material to supplier	0,28	100	0	99,72
19		Return R2 Raw Material to supplier	0,00	100	0	100,00

From the results of the Snorm De Boer in Table 3, it was found that there were several performance indicators that had a final score below 90 (<90), namely finished good planning accuracy, packaging material planning accuracy, achievement production line, and downtime SBL.

Causal Loop Diagram

Causal Loop Diagram (CLD) represent a system through three main elements: nodes, links, and feedback loops. Nodes stand for system variables that can increase or decrease over a scale. Links show causal influence positive if both variables move in the same direction, and negative if they move in opposite directions [10]. A CLD consists of variables connected by arrows that show one-way causal relationships. An arrow from variable X to Y with a plus sign (+) indicates a positive link, meaning a change in X leads to a similar change in Y if X rises, Y also rises. A minus sign (-) on the arrow signifies a negative link, where a change in X causes an opposite change in Y so if X increases, Y decreases [11]. The following is a causal loop diagram which can be seen in Figure 4.

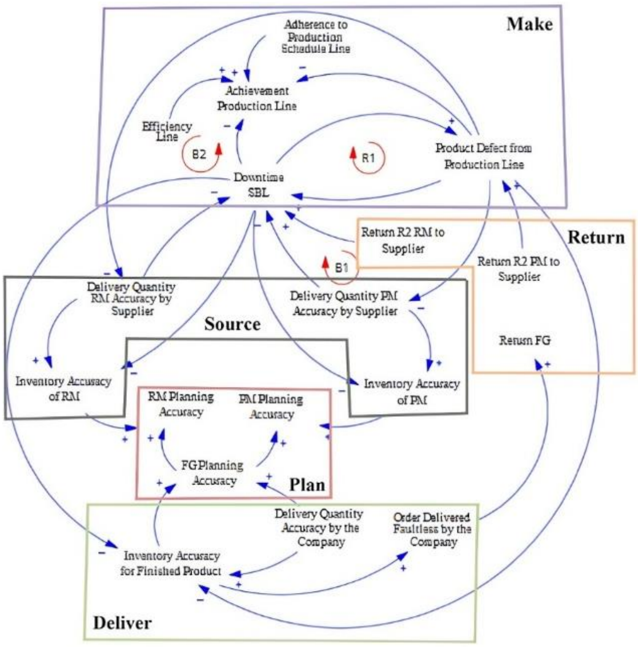

Figure 4. Causal Loop Diagram

The causal loop diagram modeling illustrates two main types of feedback in the system, namely the balancing loop (B1 and B2) which function to stabilize the system, and the reinforcing loop (R1) which reinforces changes in the system. Balancing loop B1 illustrates the relationship between the variables delivery quantity PM accuracy by supplier, downtime SBL, and product defects from production line. Increasing the delivery quantity PM accuracy by supplier contributes to the smoothness of the production process, which has an impact on reducing downtime SBL and reducing product defects from production line. A similar relationship pattern is also seen in balancing loop B2, where increasing the delivery quantity PM accuracy by supplier also reduces downtime SBL and reduces product defects from production line, so that the production system becomes more controlled and efficient. Conversely, reinforcing loop R1 illustrates a mutually reinforcing relationship between downtime SBL and product defects from production line, where increasing downtime SBL causes increasing product defects from production line, which can ultimately trigger further downtime increases. This pattern reflects a positive feedback cycle that can worsen system performance if not managed properly.

Stock Flow Diagram

Stock Flow Diagram is one form of structural representation in a dynamic system, also known as a flow diagram. This diagram clarifies the relationship between variables that have previously been described in the Causal Loop Diagram [12, 13], by showing the relationship between variables in more detail and using special symbols to present them [13]. This diagram consists of two main types of variables, namely stock and flow [12]. The following are the level/stock variables in the simulation which can be seen in the Table 4.

Table 4. Level/Stock Variables in Simulation

No.	Variable	Percentage
1	Downtime SBL	15,74%
2	Product Defect from Production Line	4,59%

The following is a form of Stock Flow Diagram in a food and beverage company which can be seen in Figure 5.

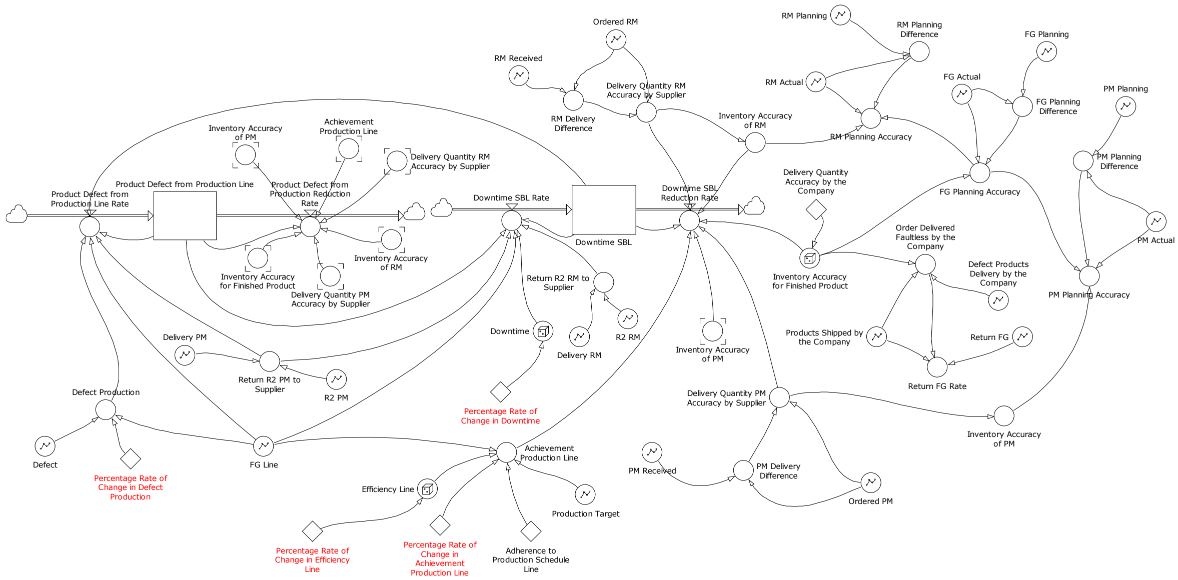

Figure 5. Stock Flow Diagram

Business As Usual (BAU)

Business As Usual (BAU) simulation is carried out by maintaining actual conditions without intervention or policy changes. The results of the BAU simulation can be seen in Figure 6 and Figure 7.

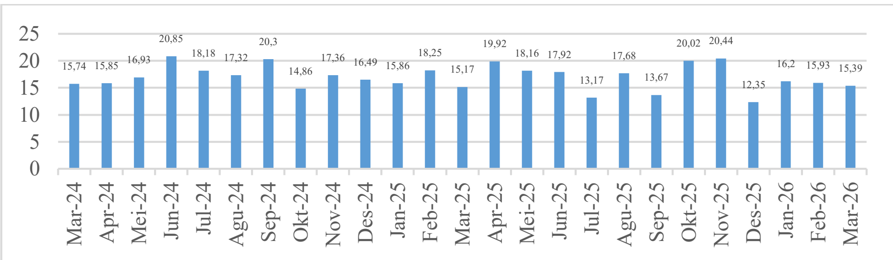

Figure 6. Bar Chart Hasil BAU Downtime SBL (%)

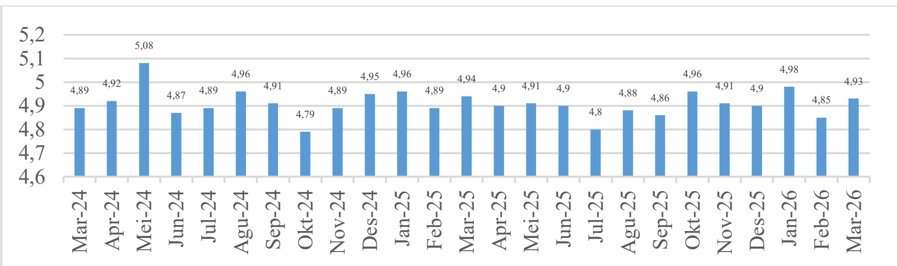

Figure 7. Bar Chart Hasil BAU Product Defect from Production Line (%)

Future Scenario Simulation

Interventions were conducted to reduce the percentage of SBL downtime and product defects from production line, which directly contributed to the improvement of operational efficiency and quality of production output. The reduction of downtime increased the effectiveness of working time, while the reduction of product defects reduced waste, rework, and customer complaints. Overall, these two indicators had a positive impact on the efficiency and quality of the production system. To achieve this, five intervention scenarios were developed, each representing a different combination of performance improvement strategies. Comparison of variable fractions in the BAU scenario and intervention scenarios 1 to intervention scenarios 5 can be seen in Table 5.

Table 5. Scenario Fraction Comparison

Variable	BAU	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5
Percentage Rate of Change in Defect Production	0	0	0	-1,5	-1,5	-1,5
Percentage Rate of Change in Efficiency Line	0	0	3,5	3,5	3,5	3,5
Percentage Rate of Change in Achievement Production Line	0	3,5	0	0	3,5	3,5
Percentage Rate of Change in Downtime	0	0	0	0	0	-1,5
Delivery Quantity Accuracy by the Company	100	100	100	100	100	100
Adherence Production Schedule Line	100	100	100	100	100	100

Post Hoc Test

One-way ANOVA is used to test the significance of research results. This means that if there is a difference, then the two or more samples are considered to be able to represent the population [14]. Each group is analyzed statistically to produce an F value. If the number of groups is more than two, the F test alone is not enough, so further testing is needed using the post hoc procedure to find out further differences between groups [15]. Post hoc test downtime SBL can be seen in the Table 6.

Table 6. Post Hoc Test Downtime SBL

(I) Scenario		Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
BAU	Scenario 1	-2,60917	0,92364	0,094	-5,4224	0,2040
	Scenario 2	2,86833*	0,92364	0,042	0,0551	5,6815
	Scenario 3	0,62500	0,92364	1,000	-2,1882	3,4382
	Scenario 4	0,85000	0,92364	1,000	-1,9632	3,6632
	Scenario 5	1,30667	0,92364	1,000	-1,5065	4,1199
Scenario 1	BAU	2,60917	0,92364	0,094	-0,2040	5,4224
	Scenario 2	5,47750*	0,92364	0,000	2,6643	8,2907
	Scenario 3	3,23417*	0,92364	0,013	0,4210	6,0474
	Scenario 4	3,45917*	0,92364	0,006	0,6460	6,2724
	Scenario 5	3,91583*	0,92364	0,001	1,1026	6,7290
Scenario 2	BAU	-2,86833*	0,92364	0,042	-5,6815	-0,0551
	Scenario 1	-5,47750*	0,92364	0,000	-8,2907	-2,6643
	Scenario 3	-2,24333	0,92364	0,268	-5,0565	0,5699
	Scenario 4	-2,01833	0,92364	0,486	-4,8315	0,7949
	Scenario 5	-1,56167	0,92364	1,000	-4,3749	1,2515
Scenario 3	BAU	-0,62500	0,92364	1,000	-3,4382	2,1882
	Scenario 1	-3,23417*	0,92364	0,013	-6,0474	-0,4210
	Scenario 2	2,24333	0,92364	0,268	-0,5699	5,0565
	Scenario 4	0,22500	0,92364	1,000	-2,5882	3,0382
	Scenario 5	0,68167	0,92364	1,000	-2,1315	3,4949
Scenario 4	BAU	-0,85000	0,92364	1,000	-3,6632	1,9632
	Scenario 1	-3,45917*	0,92364	0,006	-6,2724	-0,6460
	Scenario 2	2,01833	0,92364	0,486	-0,7949	4,8315
	Scenario 3	-0,22500	0,92364	1,000	-3,0382	2,5882
	Scenario 5	0,45667	0,92364	1,000	-2,3565	3,2699
Scenario 5	BAU	-1,30667	0,92364	1,000	-4,1199	1,5065
	Scenario 1	-3,91583*	0,92364	0,001	-6,7290	-1,1026
	Scenario 2	1,56167	0,92364	1,000	-1,2515	4,3749
	Scenario 3	-0,68167	0,92364	1,000	-3,4949	2,1315
	Scenario 4	-0,45667	0,92364	1,000	-3,2699	2,3565

Based on the results of the post hoc test in Table 6, it was found that there were several scenarios that showed significant differences in SBL downtime. From the test results, it was found that scenario 2 had a significant difference when compared to the BAU simulation results, with a significance value of 0.042 and an average difference of 2.87%, this identified that scenario 2 was able to reduce downtime significantly compared to the initial conditions. Post hoc test product defect from production line can be seen in the Table 7.

Table 7. Post Hoc Test Product Defect from Production Line

(I) Scenario		Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
BAU	Scenario 1	,20000*	0,01546	0,000	0,1529	0,2471
	Scenario 2	,11167*	0,01546	0,000	0,0646	0,1587
	Scenario 3	1,51083*	0,01546	0,000	1,4638	1,5579
	Scenario 4	1,42833*	0,01546	0,000	1,3813	1,4754
	Scenario 5	1,42833*	0,01546	0,000	1,3813	1,4754
Scenario 1	BAU	,08833*	0,01546	0,000	0,0413	0,1354
	Scenario 2	-,11167*	0,01546	0,000	-0,1587	-0,0646
	Scenario 3	1,39917*	0,01546	0,000	1,3521	1,4462
	Scenario 4	1,31667*	0,01546	0,000	1,2696	1,3637
	Scenario 5	1,31667*	0,01546	0,000	1,2696	1,3637
Scenario 2	BAU	-1,31083*	0,01546	0,000	-1,3579	-1,2638
	Scenario 1	-1,51083*	0,01546	0,000	-1,5579	-1,4638
	Scenario 3	-1,39917*	0,01546	0,000	-1,4462	-1,3521
	Scenario 4	-,08250*	0,01546	0,000	-0,1296	-0,0354
	Scenario 5	-,08250*	0,01546	0,000	-0,1296	-0,0354
Scenario 3	BAU	-1,22833*	0,01546	0,000	-1,2754	-1,1813
	Scenario 1	-1,42833*	0,01546	0,000	-1,4754	-1,3813
	Scenario 2	-1,31667*	0,01546	0,000	-1,3637	-1,2696
	Scenario 4	,08250*	0,01546	0,000	0,0354	0,1296
	Scenario 5	0,00000	0,01546	1,000	-0,0471	0,0471
Scenario 4	BAU	-1,22833*	0,01546	0,000	-1,2754	-1,1813
	Scenario 1	-1,42833*	0,01546	0,000	-1,4754	-1,3813
	Scenario 2	-1,31667*	0,01546	0,000	-1,3637	-1,2696
	Scenario 3	,08250*	0,01546	0,000	0,0354	0,1296
	Scenario 5	0,00000	0,01546	1,000	-0,0471	0,0471
Scenario 5	BAU	,20000*	0,01546	0,000	0,1529	0,2471
	Scenario 1	,11167*	0,01546	0,000	0,0646	0,1587
	Scenario 2	1,51083*	0,01546	0,000	1,4638	1,5579
	Scenario 3	1,42833*	0,01546	0,000	1,3813	1,4754
	Scenario 4	1,42833*	0,01546	0,000	1,3813	1,4754

The results of the post hoc test in Table 7 show that almost all pairs of scenarios have a significant difference in the average product defect from production line, except between Scenario 4 and Scenario 5 which do not show a significant difference (significance 1.000). Scenario 3 is recorded as the most effective, with the lowest average product defect significantly compared to all other scenarios, including BAU. so that Scenario 3 is recommended as the best strategy to reduce product defects.

Simulation Analysis Results

Based on the simulation results that have been carried out using Powersim Studio 10 software and the results of the ANOVA test, several results were obtained. The following is a comparison of the average values of the simulation results that can be seen in Table 8.

Table 8. Comparison of Simulation Average Values

Scenario	Downtime SBL (%)	Product Defect from Production Line (%)
Scenario 0	16,96	4,91
Scenario 1	19,28	5,09
Scenario 2	14,69	4,99
Scenario 3	16,41	3,64
Scenario 4	15,94	3,72
Scenario 5	15,14	3,72

Based on the simulation results in Table 8, the best scenario assessment is carried out by comparing two main indicators, namely SBL downtime (%) and product defects from production line (%), where lower values reflect better operational performance. In Business As Usual (BAU) conditions, the average SBL downtime was recorded at 16.96% and product defects at 4.91%. Scenario 1 is not recommended because it shows an increase in both indicators. Scenario 2 has the most significant decrease in downtime (14.69%), but product defects are still high (4.99%). In contrast, Scenario 3 recorded the most significant decrease in product defects (3.64%), although the decrease in downtime was relatively small (16.41%). Scenarios 4 and 5 showed balanced results, with product defects of 3.72% and downtime of 15.94% and 15.14%, respectively. The results of the post hoc test showed that Scenario 3 excelled in reducing product defects, while Scenario 2 was the most effective in reducing downtime. However, overall, Scenario 5 was considered the most balanced because it was able to reduce both indicators significantly. The decrease in downtime reflects operational efficiency, while the decrease in product defects indicates an increase in production quality, which has an impact on reducing waste, rework costs, and customer complaints. Therefore, Scenario 5 is selected as the best alternative to improve the efficiency and quality of the production system simultaneously.

CONCLUSION

Based on the results of the analysis, the following conclusions and suggestions were obtained: 1) Based on the modeling results, inefficiency and mismatch between production targets and actual output on the production line are caused by high downtime SBL and product defects from production. Both factors are interrelated and have an impact on decreasing line efficiency and achievement production line; 2) Based on the results of snorm de boer in the food and beverage companies studied, it was found that the supply chain performance results were still less than optimal, because there were still several indicators that had values below 90, such as achievement production line, downtime SBL, and planning accuracy; 3) Based on the simulation and scenario results, it was found that increasing line efficiency can improve output results and reduce downtime. Reducing product defects from production and reducing dowtime SBL can also increase line efficiency and strengthen supply chain resilience.

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