Simulation to support decision-making on project options in the refining sector of a battery company

Simulação para apoio à tomada de decisão sobre opções de projetos no setor de refino de uma empresa de baterias

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ABSTRACT

The aim of this study is to support decision-making regarding alternatives for establishing a new battery factory through a simulation-based project. The simulation was conducted considering the minimization of risks and optimization of resources to support the best decision before the plant's actual implementation. The methodology employed consists of three steps to build the model: conception (conceptual model), implementation (computational model) and analysis (operational model). The simulation provided relevant key performance indicators (KPIs) to aid decision-making, contributing to cost reduction for the company in the future. The statistical validation of the model, using the “T” test, yielded a p-value of 0.238 for the alloy refinement process at a significance level of 0.05, resulting in simulated values that closely approximate the actual results. In addition, it was observed that in production line configuration 1, scenarios with a holding ladle capacity of 100 tons and a refining ladle capacity of 80 tons resulted in negative inventories. Among the 24 scenarios tested, those numbered 20 and 21 obtained the highest dimensionless score of 7.9 on a scale of 0 to 10. These scenarios demonstrated advantages such as high furnace productivity, high refining output, low refining ladle occupancy, low lead cake stock, and low furnace input stock. This outcome highlights an optimized combination of performance indicators and their respective weights, demonstrating superior performance across multiple areas, as revealed by the simulation.

Keywords: Simulation. Optimization. Scenario. Alloys. Stock.

RESUMO

Este trabalho tem como objetivo apoiar a tomada de decisão sobre as alternativas para implantação de uma nova fábrica de baterias através de um projeto de simulação. A simulação foi executada considerando-se a minimização dos riscos e otimização dos recursos para a melhor decisão antes da implantação real da fábrica. A metodologia utilizada consiste em três passos para a construção do modelo: concepção (modelo conceitual), implementação (modelo computacional) e análise (modelo operacional). A simulação realizada trouxe relevantes indicadores-chave de desempenho (KPIs) para tomada de decisão, diminuindo custos futuros para a empresa. A validação estatística do modelo, através do teste “T”, mostrou o valor-P do teste aplicado para o processo de refinamento da liga de 0,238 com um nível de significância de 0,05, resultando nos valores simulados que estão próximos do real. Além disso, notou-se que os cenários apresentados na configuração 1 de linha de produção, os de 100 toneladas de capacidade na panela de espera e de 80 toneladas de capacidade na panela de refino obtiveram estoques negativos. Dos 24 cenários testados, os de número 20 e 21 obtiveram a maior nota adimensional de 7,9 em uma escala de 0 a 10 e apresentaram vantagem de alta produtividade dos fornos, alta produção do refino, baixa ocupação de panelas de refino, baixo estoque de bolos de chumbo e estoque baixo de insumos para o forno, pois oferecem uma combinação otimizada dos seus indicadores e seus pesos, apresentando melhores desempenhos em diferentes áreas, sendo esboçado pela simulação.

Palavras-chaves: Simulação. Otimização. Cenário. Ligas. Estoque.

Recebido em 17/07/2024. Aprovado em 18/02/2025. Avaliado pelo sistema *double blind peer review*. Publicado conforme normas da APA.
https://doi.org/10.22279/navus.v16.1969

1. INTRODUCTION

The use of computer simulation in engineering has become fundamental to guaranteeing quality and efficiency in product development. Computer simulation allows companies to create and test digital models of products, analyzing their performance in different scenarios and identifying potential problems even before physical construction.

According to Amaral (2018), complex work environments and the increasing cost of resources have led organizations to look for new solutions in terms of productivity and, above all, for more qualified and multidisciplinary professionals. Fichmann et al. (2022) report that the environment shaped by the new competitive landscape, supported by advanced technology systems, especially those linked to the area of information and communication, requires a new approach from its executive leadership, seeking better conditions and measures to define and direct the strategies and performance of organizations. Decision-making requires input that extends beyond financial information to contribute directly to guiding strategic-level changes, facilitating the implementation of potential new business initiatives, and enabling a more effective assessment of future scenarios.

Manufacturing and production line problems are commonly observed in new business units, where engineers and managers are continuously working to find methods to eliminate or reduce the challenges encountered (ZAHRAEE et al., 2014). According to Oliveira et al. (2019), manufacturing-related risks are typically categorized as follows: approximately 50% addressed financial risks, 20% pertained to risks related to occupational accidents, 20% addressed environmental risks, and only 10% covered other types of risks, including operational risks.

In the meantime, the risks arising from this work fall into the financial category, where unnecessary investments in manufacturing cause major negative impacts on the company's capex[1]. The aim of this study is to identify how simulation can help solve these problems and aid decision-making for the implementation of a new manufacturing unit for a company operating in the field of battery manufacturing.

1.1 Research problem and contribution of the article

According to Pinheiro and Mingori (2023), technology can be used as a basis for developing new strategies, including business strategies, with a focus on achieving the expected results. In this way, computer simulation has advanced and is being used more frequently in the analysis and development

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[1] Capital expenditure used by a company to acquire, update and maintain physical assets.

of production systems, with the main objectives being: to test new projects or procedures before implementing them, and to identify the most important variables of a system, such as bottlenecks and points of attention, with a view to optimizing analytical solutions (Cardoso & Junior, 2016).

According to the BNDES[2] (2013), the Brazilian automotive battery industry has been growing at high rates, benefiting from increases in vehicle production and the circulating fleet, which has led to the need for an increase in battery production in the country. This work aims to identify how simulation can help solve these problems and aid decision-making for a new unit of a battery company.

The target company manufactures automotive batteries, the components of which require different metal alloys. This company produces three types of alloys: lead-based (Pb), calcium (Ca), and antimony (Sb), which are further divided into 14 sub-alloys in the refining sector, as shown in Table 1. These sub-alloys are named by a letter and color and are used in the production of batteries for multiple functionalities. Due to the plant's growth plans and the increase in battery consumption, the company invested in a project for a new unit. To avoid inappropriate implementation and resource allocation in the real system, simulation was applied to the actual system, i.e., the refining sector of the new plant.

Table 1

Types of alloys and their suballoys

Alloys	**Suballoys**
Mole	Alloy M
Ca	Alloy S Alloy N Alloy L Alloy Y Alloy O Alloy A Alloy G Alloy D
Sb	Alloy F Alloy W Alloy B Alloy E Alloy T Alloy R

In this context, this work aims to carry out a simulation project to assist in the implementation of the new battery alloy refining unit, based on the current refining unit that is in operation. This project seeks to

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[2] Banco Nacional de Desenvolvimento Econômico e Social.

provide insights (a term used to describe an intuitive understanding or a new perspective on something) for managers through computer implementation in PROMODEL® software, with the goal of reducing waste, developing indicators, aiding decision-making, and achieving maximum efficiency and effectiveness for the battery production company's new refining unit.

2. CONTEXT AND COMPUTATIONAL TOOLS

Decisions to solve production line and manufacturing problems need to be careful and effective in order to have a positive impact on the industry's production process. Since these decisions require considerable investment, it is essential to have prior knowledge of indicators that demonstrate reliability and minimize risks (Lopes & Sardinha, 2021).

Applying the simulation method enables companies and engineers to solve complex problems and issues without the high costs of actual implementation, simply by developing the virtual model (Santos et al., 2020).

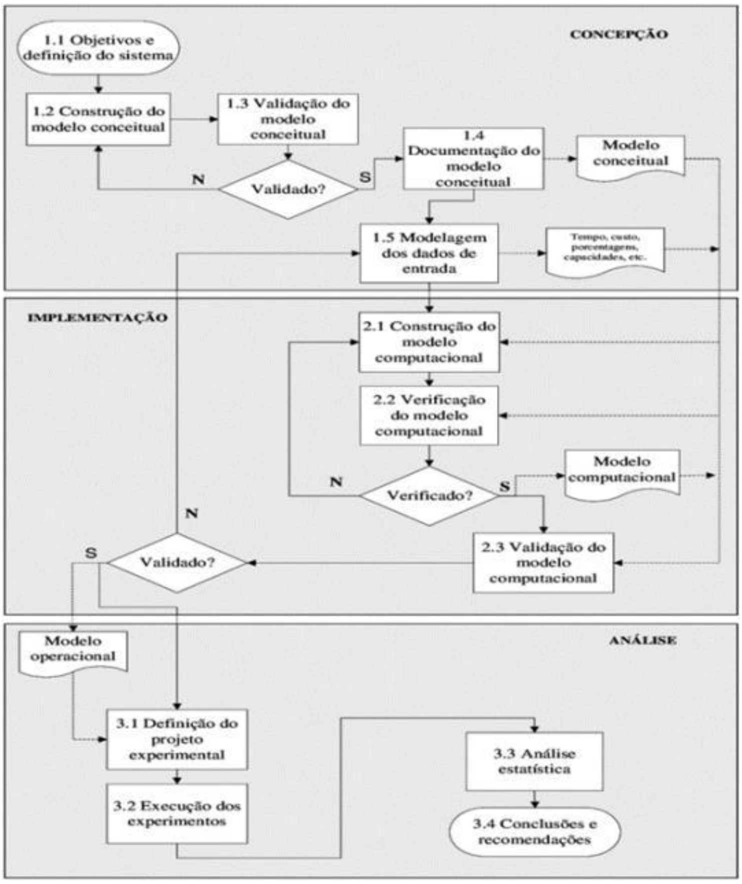
For Leal et al. (2022), simulation enables the management of problems in production systems by interacting with their variables within a digital model in computer time, without having to change the physical process. This approach allows for failure analysis, data collection, scenario testing, and process improvements in a virtual environment, thus avoiding expenses related to experimentation while optimizing the production process and supporting decision-making by managers.

PROMODEL® software is a tool used for visualization, simulation and analysis, showing the entire operation on the production line and how each process is done in succession. The results after simulation detail each process, determine the level of efficiency, and identify specific issues, such as the bottleneck that causes delays in production (Kurata et al. 2021).

3. METHODOLOGY

The methodology used in the simulation project was proposed by Montevechi (2007). This methodology consists of three well-defined and sequenced stages for carrying out a simulation project: conception (conceptual model), implementation (computational model), and analysis (operational model). These stages ensure that the project is properly structured, providing better results. Figure 1 shows the original methodology and its stages in detail.

Figure 1. Phases of a simulation project



Montevechi et al, 2007.

Conceptual modeling in the design phase was conducted using the BPMN[3] method. Implementation involved creating a computational model using PROMODEL® software, based on the conceptual model developed. Through the creation and simulation of scenarios, analyses were conducted that will assist the managers of the new refining unit in making decisions.

Face-to-face validation was chosen to validate the conceptual models in this simulation. According to Sargent (2004), face-to-face validation is defined as the act of asking or presenting individuals with extensive knowledge of the system whether the model and its behavior are satisfactory.

The input data was requested through the creation of a Cockpit (input data control tower) in Excel software by the advising engineers and passed on to the company managers, who were in charge of the project together, to fill in with data from the old refining unit and data the industry has obtained over the years, in addition to some Insider (English expression for those who have access to privileged information in companies) from their engineers.

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[3] Business Process Model and Notation

Tables 2 and 3 show the main information provided by the company. Table 2 shows the quantities of daily outputs of the sub-alloys and Table 3 shows the processing times of the alloys in the refining pans.

Table 2

Output data and safety stock of suballoys

Types of suballoys	Daily Output (Tons)	Safety Stock (5 days)
Alloys M	125,5	752.7
Alloys S	77,7	466.4
Alloys N	27,1	162.4
Alloys F	23,4	140.1
Alloys W	12,7	76.3
Alloys B	4,1	24.8
Alloys E	12,3	73.9
Alloys T	3,1	18.6
Alloys L	2,1	12.6
Alloys Y	1,2	7.4
Alloys R	1,1	6.6
Alloys O	0,9	5.5
Alloys A	0,6	3.8
Alloys G	0,3	1.9
Alloys D	0,1	0.8

Table 3

Process times

Refining Scenario	Pan	Mole (Hr)	Ca (Hr)	Sb (Hr)
1st e 2nd	1st	20	18.75	24.38
	2nd	5.63	8.13	-
	3rd	-	-	-
3rd	1st	5	18.75	24.38
	2nd	14.38	8.13	-
	3rd	4	-	-

Thus, as shown in Tables 2 and 3, the definition of rates and times, as well as the understanding of process flow, was carried out during the design phase using the BPMN method.

4. SIMULATION PROJECT

4.1 Conception

To build the conceptual model in BPMN, the company provided a technical visit to its old refining unit, where the flowchart of the battery alloy refining process was understood, from the arrival of inputs to the output of the alloys. For the new refining sector, the industry engineers proposed three production line layouts, shown in Figures 2, 3 and 4, thus presenting the first variable of the scenarios.

Figure 2. Production lines 1

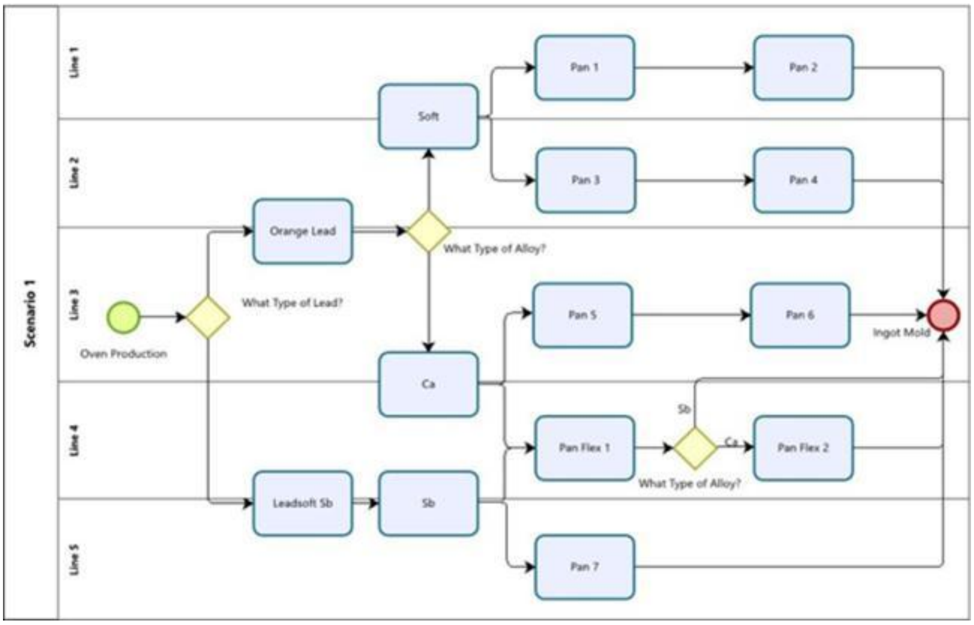
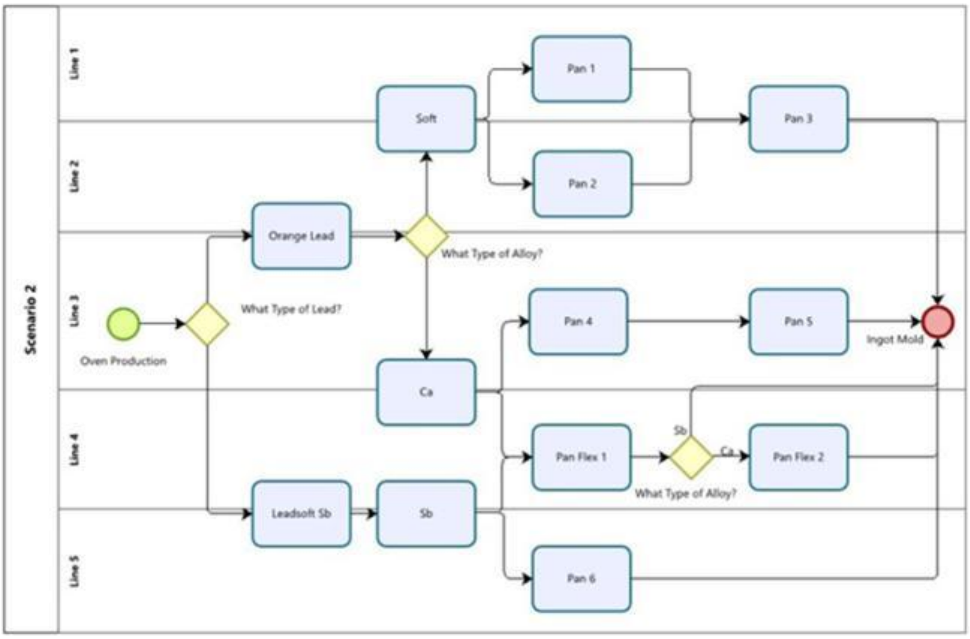
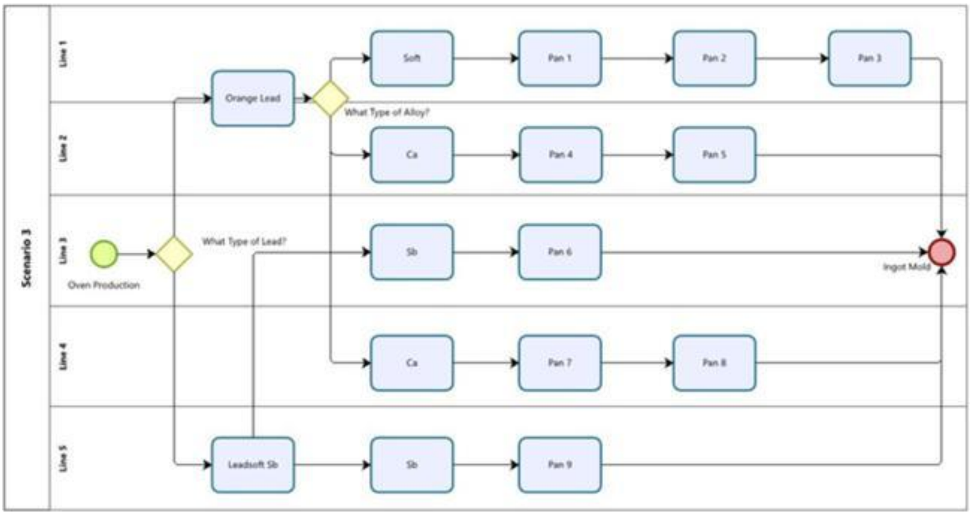


Figure 3. Production lines 2



Due to the high investment in infrastructure and the purchase of machinery, the engineers needed to be advised through data outputs on the layouts of the production lines and identify which layout[4] stood out. With this in mind, the conceptual model was diagrammed in BPMN, starting with the arrival of inputs at the furnaces and continuing through to the output of the sub-alloys in ingots.

Figure 4. Production lines 3



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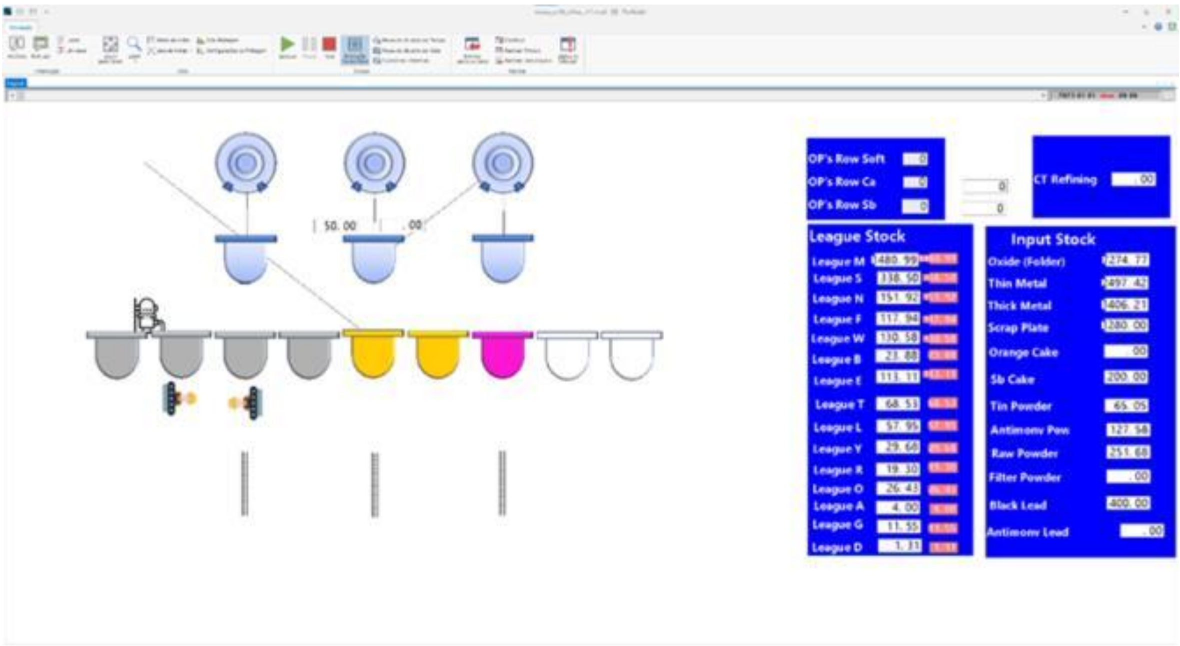
[4] Arrangement of information in a document, including format, size, distribution or graphic organization

With the conceptual model created in BPMN, the face-to-face validation process began, during which the conceptual system was presented to the company's engineers and managers. If any flaws were identified in the model, it was adjusted to arrive at a satisfactory reference.

4.2 Implementation

Based on the conceptual model, the basic computational model was created using PROMODEL® software. Figure 5 shows the design of the base computational model, built in PROMODEL®, from which variations in production lines can be applied simply by selecting the desired production line scenario in the cockpit. Additionally, the cockpit contains all the data processed by the computational model, such as process times, rates, quantity of resources, among others, making it a control tower for data inputs to the model.

Figure 5. Base computer model in PROMODEL



OP's Row Soft 0
OP's Row Ca 0
OP's Row Sb 0
0
0
CT Refining .00

League Stock
League M 480.99
League S 338.50
League N 151.92
League F 117.94
League W 130.58
League B 23.88
League E 113.11
League T 68.53
League L 57.95
League Y 29.60
League R 19.30
League O 26.43
League A 4.00
League G 11.55
League D 1.31

Input Stock
Oxide (Folder) 274.77
Thin Metal 497.42
Thick Metal 406.21
Scrap Plate 280.00
Orange Cake .00
Sb Cake 200.00
Tin Powder 65.05
Antimony Pow 127.58
Raw Powder 251.68
Filter Powder .00
Black Lead 400.00
Antimony Lead .00

During the construction of the computational model, each stage was checked for errors. If errors were found, they were corrected through observations in the model animation and by reviewing the values assumed by the variables.

Model validation is a process of testing a simulation model to find out whether the system test created has presented and provided an image of the real system that exists and is currently running. This test is conducted by comparing the output results of the real system with the output results of the simulation system. The validation test will be declared valid if the output results of the real system are the same or there is no difference with the results of the simulated system (Fajriah et al., 2023).

Statistical validation of the base model was carried out, comparing the simulation results with a sample of historical data from the old refining sector, using the “T” test for the alloy refining process, which tests for equality between two means. The tests were conducted using Excel software, and the result of the P-value of the test applied to the alloy refining process was 0.238, which is above the significance level of 0.05. This indicates that there is no difference between the test averages, indicating that the simulated values are close to the real ones.

In addition to the statistical validation of the computacional model, a second validation was carried out, in which the simulation results were analyzed together with the engineers responsible for the industry's refining sector. Using the OUTPUT VIEWER® software, dashboards were created with the data obtained from the simulation, as shown in Figure 6, and the simulation data was analyzed by exporting matrices, as shown in Figure 7. If the results showed a margin of error below the 10% stipulated by the battery company, the model was considered valid for the scenarios.

Figure 6. Simulation data dashboard by OUTPUT VIEWER

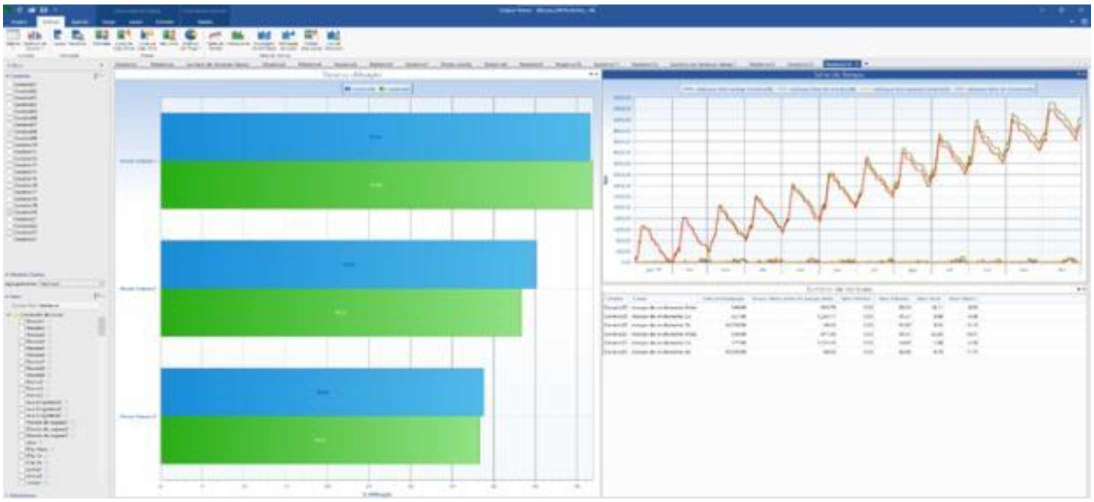
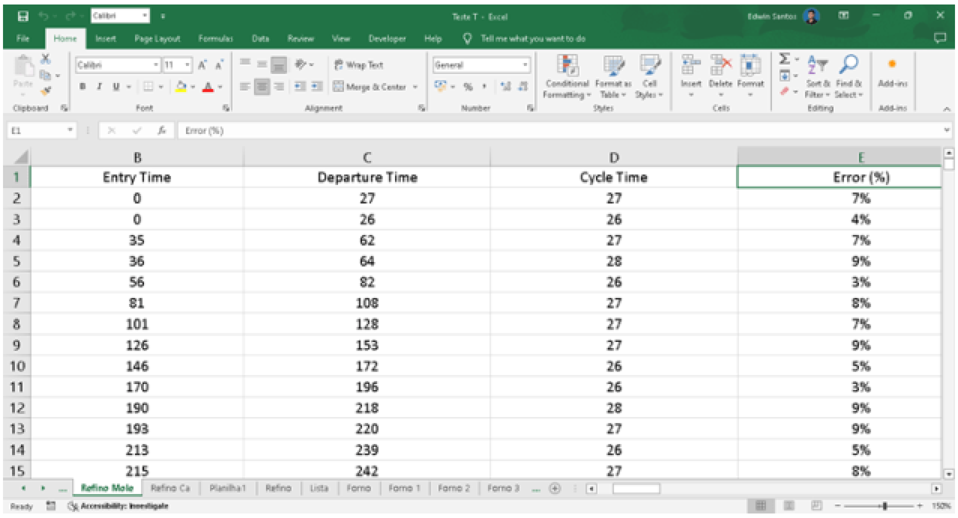


Figure 7. Data exported from the simulation using matrices



Error (%)

	B	C	D	E
1	Entry Time	Departure Time	Cycle Time	Error (%)
2	0	27	27	7%
3	0	26	26	4%
4	35	62	27	7%
5	36	64	28	9%
6	56	82	26	3%
7	81	108	27	8%
8	101	128	27	7%
9	126	153	27	9%
10	146	172	26	5%
11	170	196	26	3%
12	190	218	28	9%
13	193	220	27	9%
14	213	239	26	5%
15	215	242	27	8%

4.3 Characterization of the scenarios

The construction of the scenarios was based on the conceptual models and four variables, which included two capacities for the holding pot, two capacities for the refining pot, three production lines, and two quantities of ingot mills, resulting in a total of 24 scenarios. Table 4 presents the characteristics of these 24 scenarios and their differences.

Table 4

Scenarios

Scenarios	PE Capacity (Tons)	PR Capacity (Tons)	Production Lines	Quantity of Ingot Mold
1	100	80	1	3
2	100	80	2	3
3	100	80	3	3
4	100	80	1	2
5	100	80	2	2
6	100	80	3	2
7	100	100	1	3
8	100	100	2	3
9	100	100	3	3
10	100	100	1	2

11	100	100	2	2
12	100	100	3	2
13	50	80	1	3
14	50	80	2	3
15	50	80	3	3
16	50	80	1	2
17	50	80	2	2
18	50	80	3	2
19	50	100	1	3
20	50	100	2	3
21	50	100	3	3
22	50	100	1	2
23	50	100	2	2
24	50	100	3	2

Once the scenarios were simulated, the results of the individual simulations were analyzed. The scenarios were then filtered according to the performance requirements of the indicators requested by the company, the main filter being the stock level of the alloys over time. Thus, the scenario in which the alloys, at some point in the simulation, reached negative stock (stockouts), would be discarded for a more complete analysis. Table 5 shows the leagues' stockouts in each scenario.

Table 5
Process time

Scenario	Stockouts Suballoys Mole (Tons)	Stockouts Suballoys Ca (Tons)	Stockouts Suballoys Sb (Tons)
1	0	291	430
2	0	268	34
3	253	293	171
4	0	288	1083
5	0	273	32
6	245	290	193
7	0	1	1
8	0	0	0
9	0	0	0
10	0	0	2
11	0	0	0
12	0	0	0
13	0	301	767
14	0	262	1
15	270	297	1
16	0	302	468

17	0	263	8
18	287	296	1
19	0	9	1
20	0	0	0
21	0	0	0
22	0	8	1
23	0	0	0
24	0	0	0

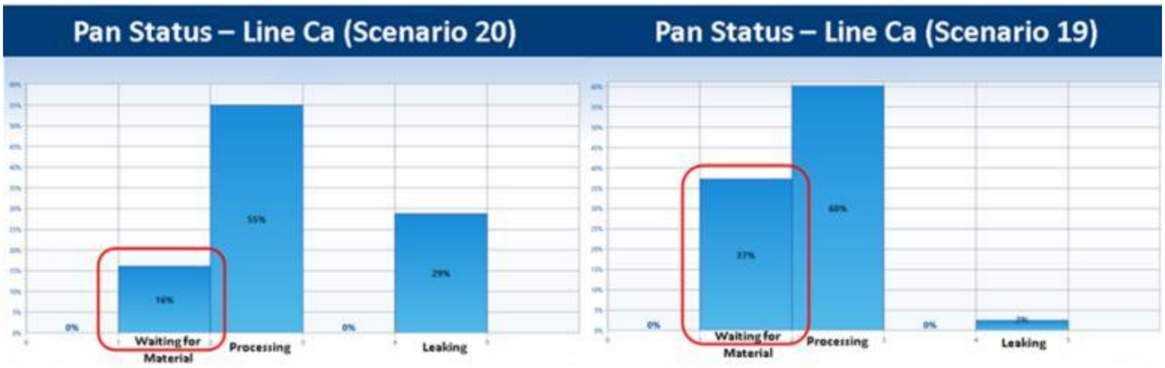
Table 5 shows that out of 24 scenarios, only 8 had a higher alloy productivity than the daily output, so they managed to keep a stock of alloys and didn't develop stockouts. Therefore, only scenarios 8, 9, 11, 12, 20, 21, 23 and 24 passed the main filter and will be analyzed further. However, a brief analysis will be conducted to understand why the other scenarios had stockouts.

4.4 Analysis of the scenarios

Analyzing the scenarios that showed stockouts (negative stock), it can be observed that those with production line configuration 1, 100 tons of capacity in the holding pot, and 80 tons of capacity in the refining pot had negative stockouts.

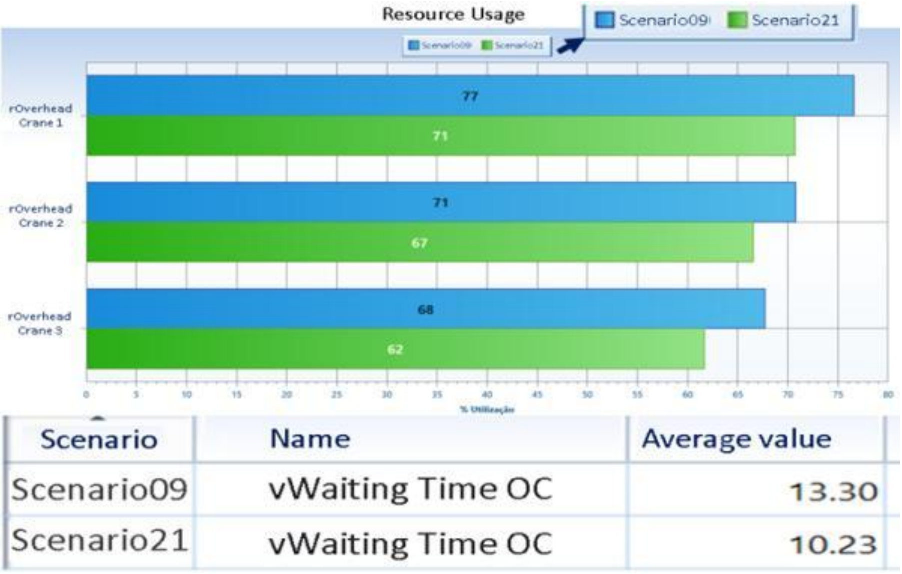
Scenarios using production line 1 experienced stockouts in the calcium and antimony alloys due to an overvaluation of the Pb-based alloy production lines and their mass production, causing a shortage of lead in the waiting pans. This shortage caused the calcium alloy pans to wait longer for material. Figure 8 shows a comparison of the status of the calcium pans between similar scenarios in which only the production line differs. Scenario 20 uses production line 2, while scenario 19 uses production line 1.

Figure 8. Comparing scenarios 20 with 19.



Critiquing the scenarios with a waiting pan capacity of 100 tons reveals the development of bottlenecks in the crane, where crane utilization increases by 16% and waiting time rises by 30%. Figure 9 shows a comparison of similar scenarios (9 and 21), with the only difference being the waiting pan capacity. Scenario 9 has a waiting pan capacity of 100 tons, whereas Scenario 21 has a capacity of 50 tons.

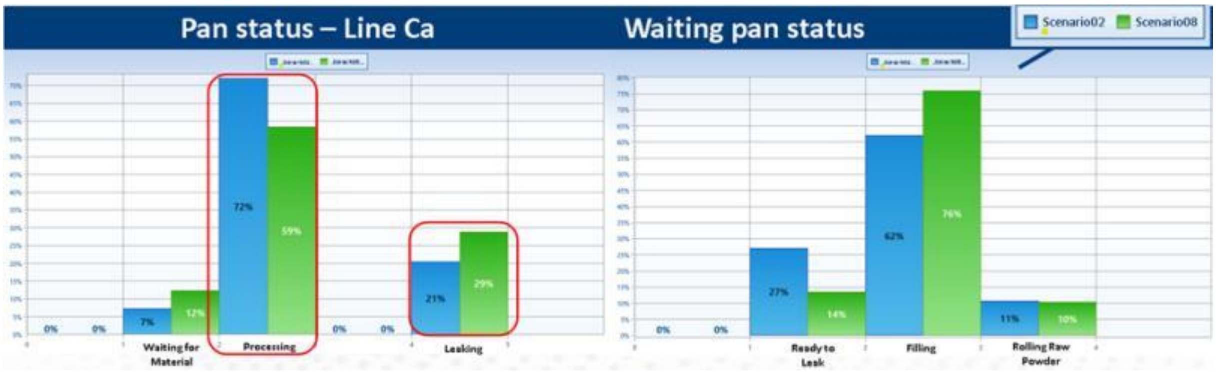
Figure 9. Comparing scenarios 9 with 21.



Scenario	Name	Average value
Scenario09	vWaiting Time OC	13.30
Scenario21	vWaiting Time OC	10.23

Evaluating the scenarios with a refining ladle capacity of 80 tons reveals that they do not meet the demand for calcium alloys, as this represents the bottleneck in the process. Figure 10 illustrates that the waiting ladle spends 13% more time waiting for the refining ladle to process the material. Figure 10 also shows that the refining pan spends 13% more time processing material, accounting for 93% utilization. Scenario 2 has a refining ladle capacity of 80 tons, while Scenario 8 has a capacity of 100 tons.

Figure 10. Comparing scenarios 9 and 21



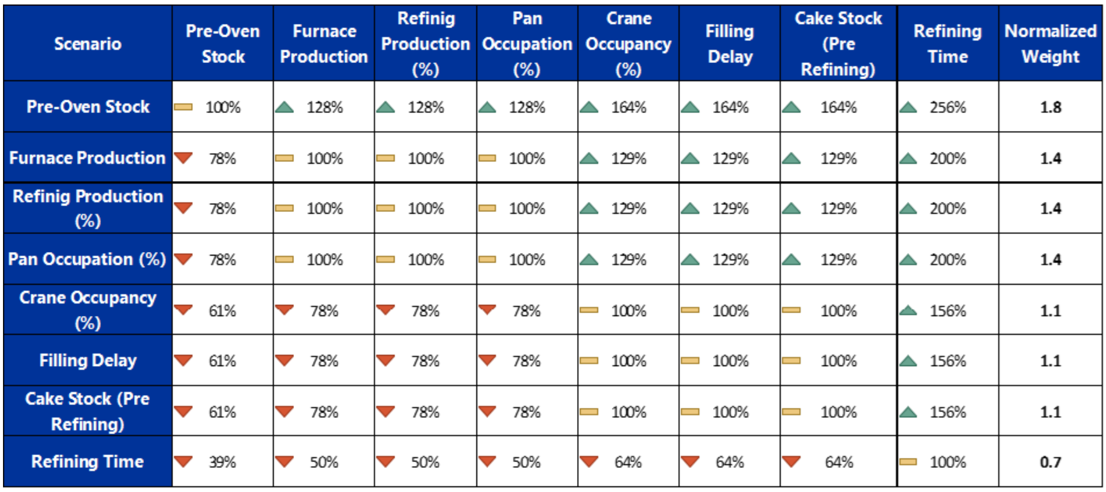
After understanding the reasons why some scenarios resulted in negative stock levels, the scenarios that made it through the first filter were subjected to a comparative analysis based on the performance of the following indicators: waiting time, ladle occupancy rate, ingot occupancy rate, crane occupancy rate, pre-furnace stock, pre-refining stock, furnace production, refining production and refining ladle filling delay. Once the indicators were defined, the next step involved calculating a weighted arithmetic average, with weights assigned to the indicators based on a two-by-two comparison. Table 6 presents how the scores are divided and Figure 11 compares the indicators two-by-two in terms of their importance.

Table 6

Grade division

Division	Note
N > 1st Quartile	10
1st Quartile > N > 2nd Quartile	7,5
2nd Quartile > N > 3rd Quartile	5
N < 3rd Quartile	2,5

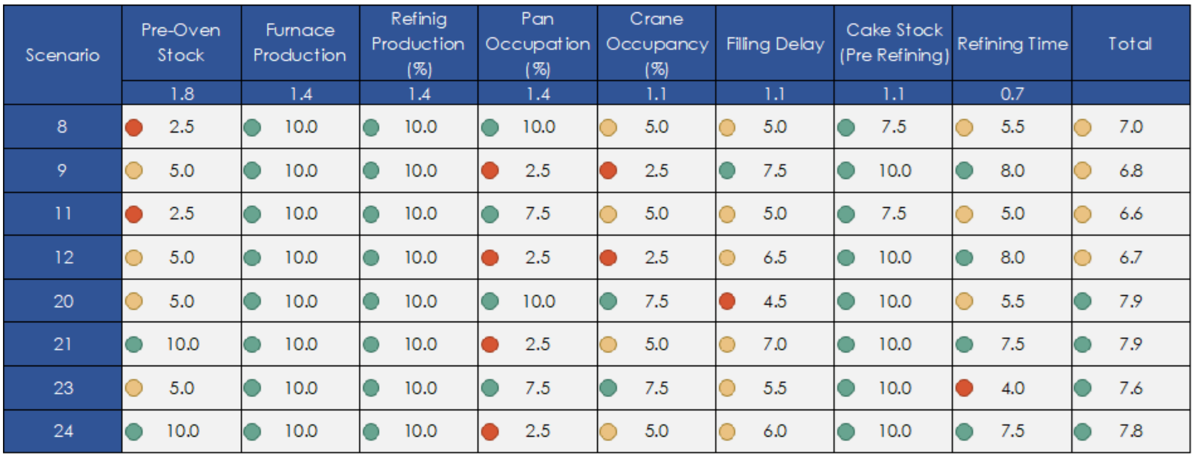
Figure 11. Indicators compared 2 by 2



Scenario	Pre-Oven Stock	Furnace Production	Refinig Production (%)	Pan Occupation (%)	Crane Occupancy (%)	Filling Delay	Cake Stock (Pre Refining)	Refining Time	Normalized Weight
Pre-Oven Stock	▬ 100%	▲ 128%	▲ 128%	▲ 128%	▲ 164%	▲ 164%	▲ 164%	▲ 256%	1.8
Furnace Production	▼ 78%	▬ 100%	▬ 100%	▬ 100%	▲ 129%	▲ 129%	▲ 129%	▲ 200%	1.4
Refinig Production (%)	▼ 78%	▬ 100%	▬ 100%	▬ 100%	▲ 129%	▲ 129%	▲ 129%	▲ 200%	1.4
Pan Occupation (%)	▼ 78%	▬ 100%	▬ 100%	▬ 100%	▲ 129%	▲ 129%	▲ 129%	▲ 200%	1.4
Crane Occupancy (%)	▼ 61%	▼ 78%	▼ 78%	▼ 78%	▬ 100%	▬ 100%	▬ 100%	▲ 156%	1.1
Filling Delay	▼ 61%	▼ 78%	▼ 78%	▼ 78%	▬ 100%	▬ 100%	▬ 100%	▲ 156%	1.1
Cake Stock (Pre Refining)	▼ 61%	▼ 78%	▼ 78%	▼ 78%	▬ 100%	▬ 100%	▬ 100%	▲ 156%	1.1
Refining Time	▼ 39%	▼ 50%	▼ 50%	▼ 50%	▼ 64%	▼ 64%	▼ 64%	▬ 100%	0.7

Figure 11 shows that pre-furnace stock is the most relevant indicator, followed by furnace production, refining production, and ladle occupancy, all with a normalized weight of 1.4. In third place are the indicators for crane occupancy, refining ladle filling delay, and pre-refining stock. Finally, refining time holds the lowest normalized weight. Figure 12 displays the score achieved by each scenario for every indicator.

Figure 12. Scenarios scores by indicator/



Scenario	Pre-Oven Stock	Furnace Production	Refinig Production (%)	Pan Occupation (%)	Crane Occupancy (%)	Filing Delay	Cake Stock (Pre Refining)	Refining Time	Total
	1.8	1.4	1.4	1.4	1.1	1.1	1.1	0.7	
8	🔴 2.5	🟢 10.0	🟢 10.0	🟢 10.0	🟡 5.0	🟡 5.0	🟢 7.5	🟡 5.5	🟡 7.0
9	🟡 5.0	🟢 10.0	🟢 10.0	🔴 2.5	🔴 2.5	🟢 7.5	🟢 10.0	🟢 8.0	🟡 6.8
11	🔴 2.5	🟢 10.0	🟢 10.0	🟢 7.5	🟡 5.0	🟡 5.0	🟢 7.5	🟡 5.0	🟡 6.6
12	🟡 5.0	🟢 10.0	🟢 10.0	🔴 2.5	🔴 2.5	🟡 6.5	🟢 10.0	🟢 8.0	🟡 6.7
20	🟡 5.0	🟢 10.0	🟢 10.0	🟢 10.0	🟢 7.5	🔴 4.5	🟢 10.0	🟡 5.5	🟢 7.9
21	🟢 10.0	🟢 10.0	🟢 10.0	🔴 2.5	🟡 5.0	🟡 7.0	🟢 10.0	🟢 7.5	🟢 7.9
23	🟡 5.0	🟢 10.0	🟢 10.0	🟢 7.5	🟢 7.5	🟡 5.5	🟢 10.0	🔴 4.0	🟢 7.6
24	🟢 10.0	🟢 10.0	🟢 10.0	🔴 2.5	🟡 5.0	🟡 6.0	🟢 10.0	🟢 7.5	🟢 7.8

Figure 12 provides an analysis of the scores for the scenarios, which delves into the advantages and disadvantages that each scenario developed during the simulation. Table 7 shows the positive and negative characteristics of the possible scenarios for the new refining sector.

Table 7

Advantages and disadvantages of the scenarios

Scenario	Advantages	Disadvantages
8	High furnace productivity, high refining production, low occupancy of refining pans	High stock of furnace inputs
9	High furnace productivity, high production, low stock of lead cakes	High occupancy of refining pans, high overhead crane utilization
11	High furnace productivity, high refining output	High stock of furnace inputs
12	High furnace productivity, high refining output, low stock of lead cakes	High occupancy of refining pans, high overhead crane utilization
20	High furnace productivity, high refining production, low refining pan occupancy, low lead cake inventory	Delay in filling refining pans

21	Low stock of furnace inputs, high furnace productivity, high refining production, low stock of lead cakes	High occupancy of refining pans
23	High furnace productivity, high refining output, low stock of lead cakes	High refining time
24	Low stock of furnace inputs, high furnace productivity, high refining production, low stock of lead cakes	High occupancy of refining pans

Among the best scenarios, 20 and 21 stood out from the others, as they presented characteristics that were considered most important for the new refining unit, as shown in Table 7 and Figure 12.

Scenario 20 demonstrated better pre-refining stock conditions, indicating a balance between the furnace, holding pot, and refining. It also developed better conditions for the use of refining pots, indicating a balance between the refining lines and dispatch. Scenario 20 also performed better in terms of crane occupancy and use of refining pans when compared to scenario 21.

For scenario 21, the pre-furnace stock indicator showed superior conditions among those evaluated, demonstrating an adequately balanced operation between the furnace, holding pot, and refining, similar to Scenario 20. In addition, this scenario provided less delay in filling the refining pans, which consequently improved the cycle time. Comparing scenario 21 with scenario 20, it is clear that scenario 21 performed better in terms of pre-furnace stock and operating time.

Scenarios 20 and 21 obtained the highest score overall on a scale of 0 to 10 and showed an advantage over the other scenarios. By analyzing these factors, we can conclude that the best scenarios are those that offer an optimized combination of their indicators and their weights, reaching a dimensionless score of 7.9.

5. CONCLUSION

This work sought to develop insights[5] to assist in decision-making on the creation of a new unit of a battery company in the refining sector. It involved developing indicators to show managers what the plant will look like with certain variables, helping to choose the best production line flow, machinery quantity, and other factors, thus reducing manufacturing costs.

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[5] A term that describes a perception about something, an intuitive understanding or a new perspective on something.

In this way, discrete-event simulation proves to be a suitable tool, as even in the absence of a real system, it can demonstrate how this system will behave in a given context, providing relevant KPIs[6] for decision-making, thus reducing future costs for the company.

In the scenarios analyzed, those with negative stockouts shared one or more of the following characteristics: they were in production line configuration 1, had 100 tons of capacity in the holding pot or had 80 tons of capacity in the refining pot. It is therefore clear that implementing a discrete simulation model offers a wide range of possibilities for conducting experiments within a procedure, anticipating possible scenarios and planning desired situations.

In the scenarios that stood out (20 and 21), it was observed that they had better pre-refining stock conditions, better crane occupancy performance, better pre-furnace stock operation and operating time. These scenarios achieved a balance between the furnace, holding pot and refining processes.

In view of the above, it can be seen that depending on the scenario adopted, it will have different characteristics and better performance in different areas, being outlined by the simulation. This achieves the objective of uncovering what was previously a 'black box' for the company's engineers and managers.

It is therefore clear that implementing a discrete simulation model provides a wide range of possibilities for conducting experiments within a procedure, anticipating possible scenarios and planning desired situations.

In addition, all simulations and analyses can be conducted without relying on an existing system, using only inputs, which allows for more precise and consistent decisions regarding changes to the system. This study was conducted with the aim of making computational projections for the plant's implementation, which would facilitate decision-making and create indicators aligned with business goals in a cost-effective manner.

For future work, it is advisable to conduct additional analyses using the simulation project to evaluate other factors, such as the cost of implementation and the feasibility of realizing the two best scenarios, in order to arrive at a definition.

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[6] Key performance indicator

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