RCMOS – Multidisciplinary Scientific Journal The Knowledge.
ISSN: 2675-9128. São Paulo-SP.

Year V, v.2 2025 | Submission: October 30, 2025 | Accepted: November 1, 2025 | Publication: November 3, 2025

Application of operational efficiency diagnostic indicators in the LSL-PY industry.

Application of operational diagnosis of efficiency indicators in the LSL-PY Industry

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Summary

This article analyzes the industrial performance of LSL-PY, a company that produces ethanol from corn grains, located in Paraguay, focusing on the operational efficiency of the belt conveyors used in the internal transport of biomass. The research, of an applied, quantitative and qualitative nature, is configured as a case study involving six employees from the production and maintenance areas. Through questionnaires and document analysis, the main causes of biomass losses and their operational and strategic consequences were identified, in addition to evaluating performance indicators between 2024 and 2025. The results revealed that recurring failures in the conveyors, such as belt breakage, material accumulation, and roller wear, compromise the reliability of the system and increase operational costs. Despite this, there was an improvement in efficiency indicators (from 176% to 195%) and productivity (from 1.76 to 1.95 tons of steam per ton of biomass), demonstrating advances in operational management. It is concluded that modernizing equipment, automating cleaning processes, implementing predictive maintenance, and using strategic indicators are fundamental to reducing losses, increasing competitiveness, and strengthening the sustainability of the production process.

Keywords: Performance Indicators. Belt Conveyors. Industrial Losses.

Abstract

This paper analyzes the industrial performance of LSL-PY, a company located in Paraguay that produces ethanol from corn grains, focusing on the operational efficiency of belt conveyors used in the internal transport of biomass. The research, applied in nature and employing both quantitative and qualitative approaches, was conducted as a case study involving six employees from the production and maintenance departments. Through questionnaires and document analysis, the main causes of biomass losses and their operational and strategic consequences were identified, in addition to the evaluation of performance indicators between 2024 and 2025. The results revealed that recurring failures in the conveyors—such as belt breakage, material buildup, and roller wear—compromise system reliability and increase operational costs. Despite these issues, improvements were observed in efficiency (from 176% to 195%) and productivity (from 1.76 to 1.95 tons of steam per ton of biomass), demonstrating progress in operational management. It is concluded that equipment modernization, cleaning process automation, predictive maintenance, and the use of strategic performance indicators are essential to reduce losses, enhance competitiveness, and strengthen the sustainability of the production process.

Keywords: Performance Indicators. Belt Conveyors. Industrial Losses.

1. Introduction

Operational efficiency is a key factor for competitiveness and sustainability.

of industries, especially in the bulk sector, where the optimization of production processes can

directly impacting profitability and reducing waste. In an industrial context, the

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ISSN: 2675-9128. São Paulo-SP.

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Internal bulk handling using belt conveyors plays an essential role in
The production chain is one of the critical points for minimizing losses and ensuring greater efficiency. However, failures in belt conveyors can result in significant waste.
raising operational costs and reducing the utilization of raw materials (Corrêa; Corrêa, 2022).

Losses of bulk materials in the logistics process of the production chain represent one of the main challenges faced by the agro-industrial sector, directly affecting efficiency and Sustainability of agribusiness. These losses can occur at various stages of the process, from from harvesting and storage to transportation and industrial processing (Ludovico; Carraro; Ferrari, 2023).

According to Laconski *et al.* (2021), the transport of bulk materials using belt conveyors is
This is a critical step in this industrial context, as any failure in the equipment or operation could cause serious problems.
This can result in significant losses of raw materials. Among the main causes are slippage, Misalignment or breakage of conveyor belts, leaks in silos and processes.
productive, excessive vibrations that cause product dispersion and improper handling during the Loading and unloading with belt conveyors. In addition to quantitative losses, which refer to
In addition to the direct reduction in the volume of available bulk cargo, there are also qualitative losses caused by...
Factors such as excessive moisture, pest infestation, and deterioration due to storage inappropriate.

From an economic standpoint, logistical losses in the production chain have an impact. This negatively impacts company profitability because it reduces the amount of raw materials available. for processing and increase operational costs (Wietcovsky; Mendonça, 2022). In addition Furthermore, this affects the competitiveness of the industry, since inefficiencies in transporters of Belts can compromise the final quality of grain-derived products, such as bran, oil, and... biofuels.

In the case of LSL-PY[1], a company focused on the production of ethanol and by-products from In the corn-grain industry, located in Paraguay, any waste can represent not only a significant financial loss, but also an impact on their productive capacity. Silva *et al.* (2024) further state that bulk losses significantly impact capacity
The productive and economic impact on industries. This problem is driven by the growing demand for Products derived from grains, mainly biofuels, have intensified due to globalization and high global consumption. LSL-PY, for example, uses bulk wood chips as biomass.

[1] Fictitious name to maintain anonymity within the industry.

[2] Bulk wood chips are volumes of fragmented wood (chipped and processed), such as sawmill waste, that are transported and stored in large volumes, usually in silos or bulk trucks, for various industrial applications.

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for feeding boilers within the corn-derived ethanol production process.

The LSL-PY Industry, located in Paraguay, operates with a high dependence on transportation. Internal bulk biomass storage for supplying boilers used in ethanol production. corn. However, recurring flaws in this process, such as accelerated wear and tear on equipment, Misalignments, obstructions, and biomass losses can compromise operational reliability. and generate significant impacts on performance indicators. The absence of mechanisms Systematic monitoring and performance analysis can reduce a company's ability to... Anticipate problems and react strategically to production bottlenecks.

In highly competitive industrial environments, the ability to integrate indicators operational aspects of the strategic decision-making process become essential to ensure the Sustainability and organizational growth. The company LSL-PY, operating in the sector of Biofuels and grain processing face challenges related to bulk losses. during the production process with industrial belt conveyors. These losses can negatively impact operational efficiency, increase costs, and reduce the sustainability of process. In this sense, the justification for conducting this study is based on the need for to find solutions to minimize the waste of raw materials and increase the performance of belt conveyors, which not only reduces costs for the company, but also contributes for the sustainability of the sector.

The loss of biomass, in addition to representing a significant financial impact, compromises operational and industrial safety. In fact, Theodoro *et al.* (2024) states that conveyors of Poorly sized conveyor belts can increase operational risks, resulting in shutdowns. emergency due to premature wear of equipment, structural damage to the system of transportation and threats such as fires, belt misalignment, production obstructions, and even... Release of toxic gases due to the accumulation of bulk materials in confined areas.

In this context, this article aims to explore the operational and strategic consequences. of the losses in the internal transport of biomass from the LSL-PY industry, in order to propose solutions strategies to minimize such consequences, in addition to analyzing diagnostic indicators of operational efficiency. To that end, this article is divided into five sections, the first of which is... A brief introduction. The second section addresses the main concepts of operations management, highlighting the indicators for diagnosing operational efficiency. The third section presents the methodology of work; while the fourth section discusses the results found. The fifth section, in turn, This presents the final considerations of this research.

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and energy. Bulk wood chips are a source of renewable biomass and can be used as fuel for heating, power generation, paper production and other products (Pereira, 2017).

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2. Theoretical Framework / Results

2.1 Operations Management

Operations management is the area of administration responsible for planning, controlling, and The execution of production and logistics processes within an organization. Its main objective is... to ensure that resources are used in the most efficient way possible to produce goods and Quality services at the lowest cost and in the shortest time possible. This management encompasses everything from... From acquiring supplies and controlling inventory to supervising production, logistics, and distribution. In industrial sectors, operations management plays an essential role in reducing Eliminate waste, improve productivity, and ensure compliance with quality standards. sustainability (Corrêa; Corrêa, 2022; Costa; Jardim, 2017; Pinto, 2025).

Corrêa and Corrêa (2022) state that efficient operations management allows that Companies can achieve greater competitiveness, reduce costs, and increase product quality. Optimizing operational processes can minimize raw material losses and improve logistics. transportation and ensure greater sustainability in production. In this sense, the authors state that the Operations management plays a strategic role, as it involves a large portion of organizational resources. and directly impacts the company's competitiveness. Its decisions must be made in a way that... aligned with the strategy, considering criteria such as cost, quality, speed, flexibility and reliability. The trade-offs between these criteria require balance to avoid dispersion of operational objectives. Therefore, managers must analyze the causes of conflicts and seek solutions by through continuous process improvement.

Coimbra (2023) and Fia Business School (2024) show that there is an interrelation between processes and operations, and this interrelationship is fundamental in production management, highlighting two Aspects: the object of the work (process) and the subject of the work (operations). The process focuses on transformation of inputs, such as raw materials and services, adding value to the final product and Analyzing production as a whole. Operations, on the other hand, focus on the agents of labor, such as... People and equipment, optimizing individual activities to improve performance. This In this way, the operation is subordinate to the process and should contribute to the overall efficiency of the company. and ensure alignment with organizational objectives.

According to Coimbra (2023), the company functions as an integrated process, in which Interdependent departments and activities generate individual results that impact the... organizational performance. To maintain harmony in these relationships, it is essential to establish indicators, allowing for continuous monitoring, performance evaluation, and the adoption of actions. Corrective measures to ensure the achievement of the company's strategic objectives. According to the author, the main...

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Challenges to efficient management include reducing operational costs and increasing...
Productivity, adaptation to new technologies, and implementation of sustainable practices. Companies
Companies that manage to balance these factors become more resilient and competitive in the global market.

2.2 Operational Efficiency in Industry

Efficiency, according to Abrahim *et al.* (2024), is related to resource management.
An action will be considered more efficient when the results achieved reflect a better
Performance. Efficiency predominates in contexts with a lower degree of uncertainty, which corresponds to...
The difference between the information needed and the information available for decision-making.

According to Corrêa and Corrêa (2022, p. 111), “efficiency is the measure of how economically effective the
An organization's resources are used to generate its results; typically, operational efficiency.
This is called "productivity" (measures that relate the outputs of the operation to its inputs).

Operational efficiency in industry refers to a company's ability to maximize its...
production of goods or services with the lowest possible consumption of resources, such as time, materials-
Raw materials, energy, and labor. An efficient operation seeks to reduce waste and optimize processes.
and improve productivity, ensuring quality and competitive costs. In practice, efficiency
Operational performance is measured by performance indicators that assess the relationship between inputs.
The resources used and the results obtained. The greater the production with the least use of resources, the greater the
efficiency (Corrêa; Corrêa, 2022; Diefenthaler, 2020).

According to Diefenthaler (2020), the pursuit of operational efficiency aims to
To improve performance through the application of various management techniques and tools, such as
Total quality, strategic partnerships, reengineering, and change management. These practices aim to...
To increase productivity and improve the quality of products and services offered to customers. Therefore...
In this way, the goal is to optimize productivity, quality, and profits by refining every aspect of the operation.

To improve operational efficiency, Coimbra (2023) suggests several strategies that
These strategies can be adopted to optimize processes, reduce waste, and increase productivity. One
According to the author, a commonly used approach is the implementation of *Lean* concepts.
Lean Manufacturing, which seeks to eliminate activities that do not add value and optimize ...
the production flow. This methodology, according to Werkema (2024), involves mapping
detailed process analysis to identify bottlenecks and implement continuous improvements, allowing that
The industry operates with greater agility and lower cost.

Werkema (2024) states that Lean Manufacturing is a methodology focused on eliminating
of waste reduction and continuous improvement of production processes. In an industrial context, waste
These can include excess inventory, unnecessary movement, waiting times, and defects in

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When applying *Lean Manufacturing,* certain essential tools must be used for products. According to Werkema (2024), the main ones are: 5S, Kaizen, Kanban, Value Stream Mapping, *Total Productive Maintenance* (TPM), Poka-Yoke, and others.

According to Lobo (2020) and Wekema (2024), the 5S (seiri, seiton, seiso, seiketsu and shitsuke) They are derived from Japanese words that mean, in Portuguese, to classify, to order, to clean, to standardize. and maintain. The goal is to promote and maintain the cleanliness and organization of the work environment for Reduce waste and increase productivity.

Kaizen is a Japanese term meaning "continuous improvement." It is a methodology focused on... to achieve rapid improvements through the structured application of common sense and creativity. Its objective is to improve a specific process or an entire value stream (Lobo, 2020; Werkema, 2024).

The word Kanban means "signal" in Japanese. Kanban is a signaling device. that authorizes and guides the production or withdrawal of items in a pull system. The most common example A common form of signaling is Kanban cards, which generally consist of simple cards. cardboard, often protected by plastic envelopes, containing information such as name and part number, external supplier or internal supplier process, storage location and location consumption. To facilitate tracking or automatic billing, a barcode can be used. printed on the card. In addition to cards, Kanban can take other forms, such as boards. metal triangles, colored balls, electronic signals, or any device that transmits the necessary information, avoiding misleading instructions (Lobo, 2020; Werkema, 2024).

Value Stream Mapping *(VSM),* according to Werkema (2024), is a tool that uses graphic icons to visually represent the sequence and the The movement of information, materials, and actions that make up a company's value stream. Generally, after Value Stream Mapping, Kaizen is used to solve problems. specific points identified.

Total *Productive Maintenance* (TPM) is a set of practices designed to ensure that the equipment in a production process is always in conditions to carry out the necessary tasks, avoiding interruptions in production (Paladini, 2025; Santos, 2022; Werkema, 2024).

Finally, Poka-Yoke, a Japanese term meaning "error-proofing," is a set of... Practices and devices developed to identify and correct flaws in a process before they occur. Make defects noticeable to customers, whether internal or external. A Poka-Yoke device. It is any mechanism that prevents an error from occurring or makes its detection immediate, facilitating... rapid correction (Paladini, 2025; Werkema, 2024).

In addition to the Lean Manufacturing strategy outlined by Coimbra (2023), Werkema (2024)

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It highlights another relevant strategy, which is the application of Six Sigma principles, which has as The objective is to reduce process variability and eliminate defects through statistical analysis. rigorous. This systematic approach, according to the author, contributes to improving the quality of products and services, in addition to reducing rework and losses, which directly impacts efficiency. operational.

According to Paladini (2025) and Werkema (2024), Six Sigma is a methodology aimed at for reducing process variability and improving product quality. It uses Statistical tools for analyzing failures and identifying opportunities for improvement. For the application In Six Sigma, the DMAIC method (Define, Measure, Analyze, Improve, and Improve) is typically used. Control), which is used to optimize processes and ensure greater efficiency.

According to Souza *et al.* (2018), in addition to these strategies, performance optimization Operational efficiency in the industry requires the adoption of advanced practices and efficient production methods. combined with specific techniques and tools for performance measurement. The authors state Performance evaluation is an essential process for companies, as it allows for the analysis of... Productivity and efficiency of production systems. The use of methods, techniques and tools of Measurement contributes to better management of productive resources, providing input for... strategic decision-making regarding the appropriate use of these resources.

2.3 Diagnosis of Operational Efficiency in Industry

According to Costa and Jardim (2017) and Pinto (2025), the diagnosis of operational efficiency It should consider five dimensions, each dimension corresponding to a category of indicators (Figure 1).

Figure 1 - The five dimensions of operational diagnosis

Source: adapted from Costa and Jardim (2017).

The first dimension, represented by EFFECTIVENESS, verifies whether the results are... compatible with the established goals and, consequently, whether the objectives are being achieved or Whether the company is making good use of opportunities. Effectiveness indicators are used to determine this. monitor how much the company has taken advantage of perceived opportunities (Costa; Jardim, 2017; Pinto, 2025). For Abrahim *et al.* (2024), effectiveness represents the ability to achieve a goal.

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previously determined, with the company being considered effective or not. This concept reflects the Achievement of the established objectives, translating the idea of fulfilling the proposed goals.

The second dimension, denoted by EFFICIENCY, verifies whether the production efforts, related to the use of scarce resources available, they are being used in accordance with the standards and benchmarks of rationality and cost-effectiveness; and whether the company is taking advantage of them. Rationally utilize time, machines, teams, and financial resources. Efficiency indicators. They indicate how much the company has leveraged its assets (Costa; Jardim, 2017; Pinto, 2025). According to Costa and Jardim (2017) and Pinto (2025), efficiency at the entrance measures the degree of rationalization or Economy in the use of resources employed; while efficiency in output is more used when dealing with very varied inputs. For Abrahim *et al.* (2024), efficiency is a A measure to evaluate the performance of processes carried out in companies, allowing for gradations. which indicate whether systems are more or less efficient. It is related to the ability to perform Performing activities correctly, quickly, at low cost, and with high quality, reflecting the idea of doing Things done well.

The third dimension, which focuses on QUALITY, investigates whether the company is... successfully meeting the expectations, needs and desires of all stakeholders (customers, (shareholders, employees, suppliers, partners, government and society). Quality indicators They show the satisfaction provided by the company to its stakeholders (Costa; Jardim, 2017; Pinto, 2025). For Corrêa and Corrêa (2022), quality is built during the production process and not It can be added to the product later. Therefore, control and guarantee actions must be in place. focused on processes and occurring simultaneously with production, especially in non-products Storage items, where later correction is not feasible.

The fourth dimension, indicated by PRODUCTIVITY, verifies the cost-benefit ratio. The benefit lies in the balance between the results achieved and the efforts made to achieve them. The indicators of Productivity metrics are used to measure the cost-benefit ratio between the efforts made and the results generated or between the inputs consumed and the outputs generated (Costa; Jardim, 2017; Pinto, 2025). For Diefenthaler (2020), productivity represents how a given process utilizes its resources, showing the relationship between what was produced and what was consumed.

Finally, the fifth dimension, represented by EFFECTIVENESS, analyzes whether the company It is fulfilling the mission for which it was created, if it is managing to provide sustainable value. in addition to all stakeholders, thus ensuring the competitiveness and longevity of The effectiveness indicators show the long-term sustainability of the business. (Costa; Jardim, 2017; Pinto, 2025). For Abrahim *et al.* (2024), effectiveness is linked to levels The organization's strategic and institutional goals require a long-term vision and actions geared towards... the future. To achieve effectiveness at different hierarchical levels, it is essential that leaders

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Managerial initiatives leverage organizational resources, stimulating employee creativity.

3. Materials and Methods

This study was conducted through applied research of a quantitative nature and
This qualitative study, configured as a case study of the LSL-PY industry located in Paraguay, is a case study.
The quantitative approach involves the collection and analysis of objective data, such as performance indicators.
allowing the identification of patterns and variations based on concrete numbers. The qualitative aspect, on the other hand,
It seeks to understand the perceptions of employees and managers regarding operational problems.
capturing impressions that enrich the interpretation of phenomena and guide improvements.

This study is classified as applied research because it aims to solve a problem.
Practical: Losses and inefficiencies in belt conveyors in the LSL-PY industry, through the
analysis of operational indicators. Furthermore, it has an exploratory and explanatory character, as it seeks...
Identify factors that affect equipment performance and understand the causes of these factors.
occurrences, using questionnaires applied to experienced professionals.

Finally, this is a case study, as it analyzes a real-world phenomenon in depth.
within a specific organizational context. According to Yin (2015), this method is suitable
to understand complex situations while preserving the characteristics of the environment being studied,
justifying its application in LSL-PY.

The subjects of the research are production area employees and maintenance technicians.
who work directly in the operation, maintenance and supervision of equipment
Belt conveyors for bulk materials at LSL-PY Industry. The selection of participants was made by
intentionally, considering their practical experience and involvement with the process being analyzed,
being nominated by the industry manager.

In the production sector, the following responded to the questionnaire: (i) the boiler operator who works
working rotating shifts in the industry for over six years, allowing for a cross-sectional view of
The process, both in terms of situations that occur during the day and in terms of situations...
recurring over the years; (ii) the shift leader who has worked rotating shifts for more than six years.
in the industry, also allowing a cross-sectional view of the process; and (iii) the shift supervisor of
morning, who has also worked at the company for over six years, and is very familiar with the process of
production.

In the maintenance sector, the following responded to the questionnaire: (i) the maintenance planner of
day shift, who has been with the company for less than three years; (ii) the mechanical supervisor of the day shift,
who has been with the company for more than six years; and (iii) the CPCM analyst, also on the day shift, with
Less than three years of work experience at LSL-PY.

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The names of the six respondents, as well as the name of the industry, will not be disclosed.
due to a request for anonymity.

3.1 Data Collection and Analysis

The procedures for carrying out this research involved two main stages: (i)
exploration of the operational and strategic consequences of losses in internal transportation of
biomass and recommendations for the identified problems; and (ii) calculation of the indicators of
Operational efficiency diagnosis. For this purpose, data collection was carried out through an application.
questionnaire.

Initially, a questionnaire, which served as a diagnostic tool, was administered to the six.
employees directly involved in the operation and maintenance of belt conveyors for
bulk materials. This instrument was designed to identify and investigate the conditions of
belt conveyors; and to point out the operational and strategic consequences of losses in
Internal biomass transport. The questions addressed technical, operational, and perceptual aspects.
about how the equipment works.

The questionnaire contains 20 multiple-choice questions and three open-ended questions, and is divided into...
Three blocks. The first block is the respondent's profile, where only the job title or function matters.
The first section contains questions about the position held, the length of experience in the field, and the work shift. The second section contains questions about the position held, the length of experience in the field, and the work shift.
related to the conditions of the conveyor belt, which will help in identifying variations in
The third section inquires about the perception of the operation and the process performance.
Operational and strategic consequences of losses in the internal transport of biomass. This article
It only addresses the third section of the questionnaire.

The questionnaire was administered in the industry on August 26, 2025, where the researcher...
accompanied the interviewee during their work shift to collect the questionnaire information.
at the most convenient time for the worker.

The objective questions from the questionnaire were presented in graph format. The data
Qualitative data, obtained from open-ended questionnaire responses, were transcribed in order to highlight the...
operational and strategic consequences of losses in the internal transport of biomass by
perception of LSL-PY employees. This allowed for the interpretation of information in a way
systematic, seeking to identify patterns of perception, recurring behaviors, and aspects
Critical factors observed in the work environment.

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3.1.1 Indicators

According to the five dimensions of operational diagnosis, in order to carry out the
For an initial diagnosis, it is necessary to calculate these five dimensions. However, as already pointed out
Previously, the fifth dimension (effectiveness) did not apply to the reality of the process studied by
Therefore, in this research, only four dimensions were calculated. The formulas for each of them are...
presented in equations 01 to 04, according to Costa and Jardim (2017) and Pinto (2025).

$$á = \frac{\qquad}{\qquad} * 100$$

$$\text{and} = \frac{\qquad}{\qquad^{\text{the}}} * 100$$

$$= \frac{\qquad}{u \qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad\qquad^{\text{here}}} * 100$$

$$= \frac{\qquad^{i}}{\qquad}$$

The calculation of these indicators, taken together, allowed for the analysis of the variation in operational performance indicators related to bulk conveyor belts, enabling the proposal of improvements not only for the conveyor belts themselves, but also for the management of the production process.

4. Results and Discussion

This section presents the operational and strategic consequences identified by
respondents to the survey, and a discussion about the results of the operational efficiency indicators.

4.1 Data Collection and Analysis

To identify the operational and strategic consequences of losses in transportation.
Internally, regarding biomass, 5 questions were developed, which are distributed within Block 3 of
questionnaire. This subsection, therefore, presents an analysis of these questions.

From Graph 1, it can be seen that the analysis of the possible causes of equipment downtime...
This highlights a multitude of factors that directly impact operational continuity and, therefore
As a result, the strategic efficiency of the production process.

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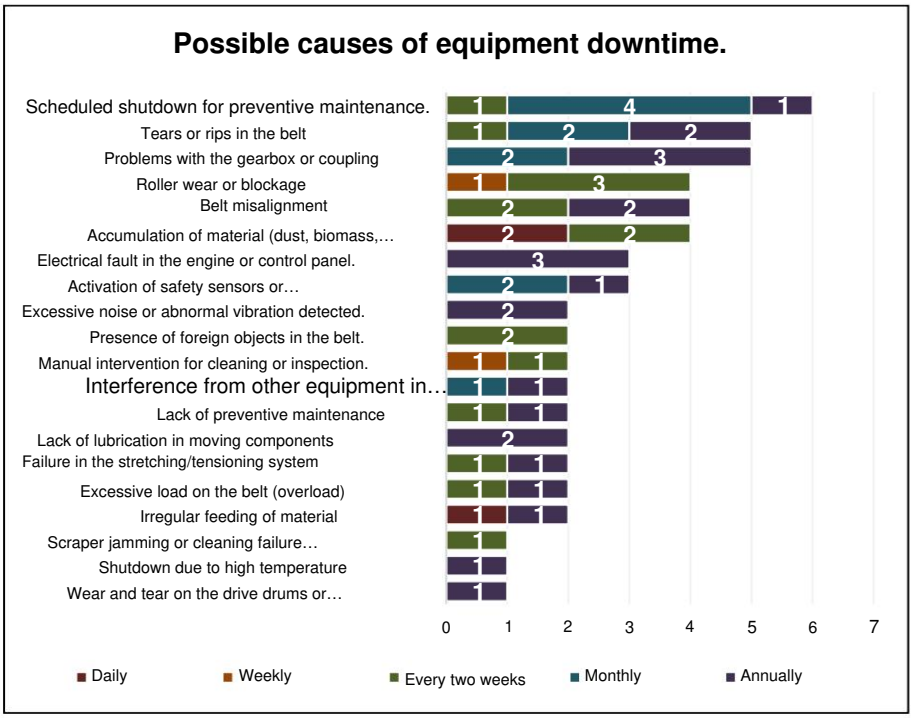
Figure 1 - Possible causes of equipment downtime



Source: research results (2025).

Analysis of the possible causes of equipment downtime reveals a predominance of failures related to both structural factors of the belts and deficiencies in the planning of maintenance, which aligns with the reflections of Corrêa and Corrêa (2022) and Costa and Jardim (2017) Regarding the need to align operational efficiency with systematic diagnostics. The most important factor.

The recurring event was scheduled maintenance shutdowns, selected six times (with the highest number of scheduled maintenance shutdowns). (monthly incidence, but also recorded bi-weekly and annually). This result shows that, Although there is concern about preventive maintenance, there is still a high dependence on it. type of intervention, which implies frequent stops and opportunity cost due to interruption of the operation.

Another group of high-impact failures is associated with belt ruptures or tears. (four occurrences) and problems in the reducer or coupling (five occurrences), both with monthly and annual records. These failures are strategic, as they involve critical components whose Replacement requires a high investment and significant downtime. Wear and tear or locking, on the other hand, can occur. Roller failure (four occurrences) and belt misalignment (four occurrences) highlight the fragility in the continuous performance of carriers, problems that, in addition to compromising the productivity gains, but they generate increased energy consumption and risks of secondary damage to other areas. components.

The accumulation of material (dust, biomass, and waste) also appears to be a significant factor. (four occurrences), reflecting failures in the cleaning and sealing system. This condition increases the The need for manual labor for cleaning increases the risk of fires, in addition to...

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accelerate wear and tear on metal structures.

Electrical faults in motors or control panels were reported three times, with annual frequency, and the activation of safety sensors, also mentioned three times, especially Conducting annual surveys reinforces the importance of electrical reliability for operation. Furthermore, The following occurred: excessive noise or abnormal vibration, presence of foreign objects, system failure. stretching/tensioning, belt overload, irregular material feed, lack of lubrication in moving components, lack of preventive maintenance, manual intervention for cleaning or inspection and interference from other equipment, all with two occurrences each, indicating specific problems that could escalate into serious failures if left unmonitored. appropriately.

Finally, less frequent failures, such as scraper jamming, wear on the drums of activation or return, and shutdown due to high temperature, although they only occurred Each instance should not be disregarded. These events may occur infrequently, but... They represent significant risks when they occur, both to the integrity of the equipment and to the belt as well as for operational safety.

Strategically, these results demonstrate that the current system still operates under strong The influence of scheduled and corrective shutdowns, resulting in additional costs and loss of efficiency. and security risks, an aspect that reinforces the analysis by Abrahim *et al.* (2024) on the relationship between Effectiveness, efficiency, and organizational performance. The recurrence of mechanical failures (wear and tear of Rollers, misalignment, and breakage) associated with the accumulation of residue indicates the need for greater investment in automation, more efficient cleaning equipment, monitoring Continuous monitoring through sensors and reinforcement of predictive maintenance practices. Such measures, if incorporated Strategic maintenance planning can significantly reduce the number of shutdowns. unscheduled maintenance increases operational availability and ensures greater competitiveness. long-term organization, strengthening the competitiveness and sustainability of the industry. as discussed by Araújo and Aguiar (2024), Pereira (2021) and Pimentel (2021).

Given the identified shortcomings, the adoption of a set of measures is recommended. strategies aimed at reducing unscheduled downtime and increasing reliability operational. First and foremost, it is essential to strengthen preventive maintenance programs and Predictive, migrating from a corrective model to more structured practices that utilize indicators. Wear sensors, vibration sensors, temperature sensors, and real-time alignment. In addition, it should- Automating belt cleaning systems reduces reliance on manual intervention. and minimizing the accumulation of dust and biomass, which proved to be one of the main factors causing shutdowns.

In terms of asset management, standardization and modernization of the following is recommended. Critical components, such as rollers, scrapers, and reducers, ensuring technical compatibility and

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ISSN: 2675-9128. São Paulo-SP.

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longer service life, as suggested by Anjos Junior *et al.* (2019), Fernandes (2022) and Sant'Ana e Silva (2020), when pointing out the importance of KPIs to guide strategic and maintenance decisions. Strategies for maintaining a minimum inventory of spare parts should also be considered to avoid Prolonged stoppages due to delays in restocking. Another crucial point is investment in Technical training and staff skills development, ensuring that operators and maintenance personnel are... capable of identifying early signs of failure and making immediate adjustments, aligning with best practices. continuous improvement proposals by Lobo (2020), Paladini (2025) and Werkema (2024).

Finally, at a broader level, it is recommended that the organization adopt indicators of Performance (KPIs) of carrier reliability and availability, integrating them into Strategic planning and production goals. In this way, in addition to reducing operational costs By increasing security, the company can enhance its competitiveness in the market, consolidating a A culture of operational excellence based on modern maintenance and industrial management practices.

With regard to the assessment of visible biomass losses during transport, 100% of Respondents identified the occurrence of losses at a low level (less than 5%). This loss refers to- whether it refers to the raw material, that is, the bulk biomass itself; however, this is already sufficient to generate risks. daily manual cleaning requirements and accumulations along the conveyor belt structure which impair the performance and lifespan of the equipment.

Although losses are below 5%, Costa and Jardim (2017) and Pinto (2025) state that, Even small losses impact productivity and competitiveness, since losses Continuous maintenance generates indirect costs and compromises the sustainability of the operation. Furthermore, although... Although reduced in percentage terms, this recurring loss highlights systemic failures in the operation of equipment, the effects of which are amplified in terms of indirect costs, the need for rework and increased demand for labor.

To complement the analysis, respondents were asked to give their opinions on how These problems affect operations management ("In your opinion, how much do these problems affect the operations management?"), and to report the operational and strategic consequences ("What are the operational and strategic consequences of losses in the internal transport of biomass?") problems. The complete answers are presented in Table 1.

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Table 1 - Opinion on the problems and their consequences

Respondent: How do problems affect operations management?		Operational and strategic consequences
Boiler operator	Increased rework rates, increased labor costs due to rework, and reduced equipment lifespan lead to higher expenses, more maintenance planning, and consequently, increased costs.	The consequences fall on the conveyor belt, since for the production process the losses are insignificant, but consequently there is a decrease in the useful life of equipment and components due to contamination caused by losses in the conveyor belt and its surrounding environments. For example, the power generator located near the conveyor belt has already tripped twice in the plant due to excess dust and suspended particles that accumulate in the generator's drive motor, causing it to shut down.
Leader of shift	Temporary malfunction of the conveyor belt amperage control.	More manpower needed for cleaning.
Supervisor	Loss of material, corrosion of the structure, premature wear of the belt.	Increased workforce in the cleaning sector.
Planner Maintenance / Planner	I believe the biggest issue would be the rework generated by the wear and tear of the assets.	The consequences would include the need for daily manual cleaning, fire hazards, rework in maintenance, among others.
Supervisor Mechanic	Increased workforce and food processing equipment. Fuel consumption.	Requires manual cleaning, fire hazard. Effective strapping strategy and sealing.
Analyst CPCM	Increased labor and belt drive operation reserve.	Manual cleaning, risk of fire.

Source: research results (2025).

The perceptions reinforce what Abrahim *et al.* (2024) and Lobo (2020) expose, which is the relationship between efficiency and effectiveness with operational costs, rework, and risks, since the reports They point to increased labor costs, fire hazards, and reduced equipment lifespan as contributing factors. the main operational and strategic consequences. Furthermore, a gap is noted between the recognizing the problems and effectively implementing solutions, identifying barriers. Organizational factors that limit the evolution towards continuous improvement practices.

The main problems identified in the operation of the equipment are associated with factors Mechanical and structural problems, such as amperage system malfunctions, material loss, and corrosion. structural problems, premature belt wear, and failures in the drive of auxiliary equipment. In addition Furthermore, the impact of continuous wear and tear on assets stands out, generating rework and increased needs. Constant corrective maintenance is required, reducing the operational availability of the system.

From an operations management perspective, the most frequent effects are linked to a significant increase in the workforce dedicated to manual cleaning. Many reports indicate that This need is daily, which increases operational costs and takes workers away from other activities. higher added value. Furthermore, the accumulation of waste resulting from losses generates risks of... fire, rework in maintenance, and even increased energy and fuel consumption due to activation of additional machinery to compensate for transportation failures.

In strategic terms, such problems compromise the efficiency and competitiveness of operation. The persistence of losses, even on a small scale, represents a waste. Continuous supply of materials, which, added to the increased costs of cleaning and maintenance, has an impact. directly impacts the profitability of the process. Furthermore, there are safety risks (fires and failures).

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(Serious mechanical problems) constitute critical vulnerabilities, requiring increased attention in planning. Investments.

Therefore, the findings reinforce the need for modernization of transporters and of Implementation of technologies that minimize losses and reduce dependence on corrective actions. From From a strategic point of view, the transition to a more preventive and automated management model of Assets can not only reduce operating costs, but also increase reliability. production process and the long-term sustainability of the operation.

Based on the observed consequences, the following measures are recommended. strategies outlined in Table 2.

Table 2 - Recommendations for the identified problems

Problem	Recommendations	Related authors and theoretical foundations
Reducing visible bulk losses	• Implement more efficient containment systems, such as sealing skirts and more durable scrapers. • Continuously monitor critical leak points for immediate correction.	Corrêa and Corrêa (2022) – loss control and operational efficiency. Diefenthaler (2020) – material losses and impact on OEE. Werkema (2024) – continuous improvement and waste reduction.
Equipment modernization	• Replace belts and components susceptible to corrosion with materials that are more resistant to abrasion and moisture. • Incorporate amperage and vibration monitoring sensors, ensuring greater preventative control over structural failures.	Viana (2022) – predictive maintenance and technological modernization. Gregório (2018b) – condition-based inspections. Lima and Bauermann (2023) – energy and operational efficiency.
Cleaning and risk mitigation	• Automate cleaning processes with secondary scrapers and self-cleaning systems to reduce the need for manual intervention. • Implement fire safety measures, such as temperature detectors and sprinkler systems, in higher-risk areas.	Corrêa and Corrêa (2022) – industrial organization and cleaning. Costa and Jardim (2017) – risk mitigation and operational effectiveness. Santos (2018) – TPM and automation as failure prevention.
Workforce optimization	• To redirect workers to higher value-added activities by reducing their reliance on daily manual cleaning. • Promote regular training on preventive inspection and real-time fault response.	Corrêa and Corrêa (2022) – efficient human resource management. Viana (2022) – capacity building and preventive response to failures. Werkema (2024) – valuing the team and continuous improvement.
Integration into the organizational strategy	• Define specific key performance indicators (KPIs), such as loss rate, frequency of manual cleaning, and cost of corrective maintenance. • Incorporate these indicators into strategic planning to support investment decisions and the prioritization of technological improvements.	Diefenthaler (2020) – integration of maintenance indicators into the strategy. Corrêa and Corrêa (2022) – management by indicators and systemic efficiency. Werkema (2024) – integration between operational performance and competitive advantage.

Source: own elaboration (2025).

The modernization proposals (sensors, automation, component standardization) are in line with the literature on performance indicators and strategic asset management (Sant'Ana; Silva, 2020; Fernandes, 2022). However, critical analysis suggests that the viability Economic factors must be carefully considered, especially in short-term scenarios where The complete replacement of equipment is already planned. Such recommendations should be carefully analyzed, as some may be economically unfeasible for the company if This person intends to replace the equipment in the short term.

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4.2 Operational Efficiency Diagnostic Indicators

For the analysis of the variation in operational performance indicators, the following were analyzed: production and maintenance control for the company, verifying the variables that the company monitors, such as such as biomass consumption, steam generation, and maintenance history, which allowed for calculations. The indicators of effectiveness, efficiency, productivity, and quality. This subsection, therefore, presents an exploration of these documents, showing the performance indicators obtained from January 2024 to August 2025.

For LSL-PY Industry, a company that operates on a large scale in the sector of For biofuels and corn-derived products, KPIs related to productive performance take on a strategic role. because they provide visibility into the efficiency and sustainability of the industrial process. A The importance of these indicators is directly linked to the constant pursuit of loss reduction. Resource optimization and increased competitiveness are fundamental aspects in a sector that demands... High productivity and strict cost control.

The analysis of performance indicators revealed different aspects of the process. productive between January 2024 and August 2025, allowing for an understanding of both the advances The results have been achieved regarding the critical points that still compromise the overall efficiency of the operation. Table 3 presents a general comparison of the indicators.

Table 3 - Comparison between accumulated performance indicators: 2024 and 2025

Performance of indicator	2024 Cumulative	Cumulative figures for 2025*	Trend
Effectiveness	53%	50%	ÿ Reduced achievement of global goals
Efficiency	176%	195%	ÿ Greater resource utilization
Productivity	1.76 tons of steam per tons of biomass	1.95 tons of steam per tons of 100% biomass	Significant growth in daily production.
Quality	100%		ÿ Stability and consistency

*Accumulated up to August.
Source: own elaboration with data provided by LSL-PY (2025).

A comparison between the cumulative performance indicators for 2024 and 2025 (up to August). reveals a generally positive evolution in operational results, although some aspects still require managerial attention. Overall, the data indicate improvements in efficiency and productivity, which demonstrates greater control over processes and better use of resources. available resources.

Regarding effectiveness, a slight reduction is observed, from 53% in 2024 to 50% in 2025. which suggests that, although the processes are more optimized, some of the established objectives are not being met. is being fully achieved. This result may be related to the complexity of the goals or

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There are occasional failures in coordination between the production and administrative sectors. On the other hand, the Efficiency showed significant growth, increasing from 176% to 195%, indicating that... The company managed to achieve more with the same resources, reducing waste and improving... Time and productivity management.

Productivity also showed significant improvement, rising from 1.76 to 1.95. tons of steam per ton of biomass, an increase of approximately 10.8%. This Growth can be a direct consequence of improved equipment availability, which It increased from 72% to 82%, showing a reduction in downtime and greater operational reliability. These two indicators are strongly interconnected, and their evolution suggests that there has been progress in Preventive maintenance and production planning. On the other hand, quality remained stable. 100% over both years, which demonstrates consistency in the standardization of processes, consolidating a strong point of the operation.

In summary, the 2025 scenario shows a trend of growth and consolidation of processes, but it also points to the need to improve the achievement of strategic goals and the The pace of equipment operation will ensure even more significant results in the coming days. periods.

Final Considerations

Research into the industrial performance of LSL-PY stemmed from the need to to understand the impacts of bulk losses on the internal process of belt conveyors and to seek solutions that would increase the company's operational efficiency. This concern is justified. due to the strategic importance of biomass transportation in the production chain, since any Failure in this system directly compromises productivity, safety, and operating costs. Thus, the study sought to integrate knowledge of management, planning, and process control. to the practical reality of an industry, demonstrating how administrative tools can be applied to solve technical and strategic problems. To this end, the study aimed to explore the Operational and strategic consequences of losses in the internal transport of biomass in the industry. LSL-PY, in order to propose strategic solutions to minimize such consequences, as well as to analyze Operational efficiency diagnostic indicators.

Regarding the operational and strategic consequences of losses in transportation. Internal biomass, research has shown that such losses affect not only productivity, but also sustainability and the company's institutional image. Recurring failures in Conveyors generate additional costs due to corrective maintenance, waste of raw materials, and... environmental risks, in addition to reducing the organization's competitiveness in the biofuels sector.

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This finding reinforces the importance of integrated management, in which operational efficiency and

Sustainability and the relationship between industrial management and industrial management must go hand in hand. Thus, the study demonstrates the role of the industrial manager.

It goes beyond technical supervision, also encompassing risk management, costs, and sustainability.

The combined analysis of performance indicators reveals a complex picture of an operation in which significant advances coexist with structural limitations that compromise the Consolidation of sustainable results. In general, the effectiveness indicators reveal that the The organization is experiencing difficulties in fully meeting its established goals, remaining... around 40% to 50% during most of the analyzed period, with only a few peaks of Performance above 80%. This behavior suggests a misalignment between planning and... execution, reflecting the need for greater realism in defining objectives and greater integration. between strategic and operational areas.

On the other hand, efficiency and productivity indicators demonstrated the capacity of organization in extracting good results from available resources, reaching high levels in specific periods, as observed between the end of 2024 and the beginning of 2025. These moments They reveal potential for operational excellence, but instability and difficulty in maintaining levels are also a concern. Consistent changes over time indicate weaknesses in control and standardization processes. When efficiency and productivity fall, effectiveness is directly impacted, compromising the... Meeting targets and the competitiveness of the operation.

The most consistently positive aspect of the analysis lies in the quality indicator, which It remained at 100% throughout the entire evaluation period. This performance demonstrates robustness in process control. However, while excellence in quality eliminates waste and Rework, on its own, is not sufficient to improve the overall performance of the operation.

Therefore, the analysis demonstrates that the biggest challenge for LSL-PY is not in achieving peak performance, but rather in consolidating management, maintenance, and control practices that allow transforming these isolated moments of high efficiency into a continuous pattern. Only through from the alignment between achievable goals, standardized processes, preventive and predictive maintenance, In addition to greater rigor in performance management, it will be possible to consistently increase the... Indicators of operational efficiency and, consequently, the company's global competitiveness.

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