



# **Supply Chain Performance Evaluation in the Pulley Manufacturing Industry Using Supply Chain Operations Reference and Analytical Hierarchy Process**

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**Abstract.** Supply chain performance is critical to the efficiency of make-to-order manufacturing systems, where waste such as waiting, rework, unnecessary motion, overprocessing, and transportation still occurs at several workstations. These inefficiencies prolong production time and reduce overall effectiveness. This study aims to measure supply chain performance, determine the relative importance of performance metrics, and establish improvement priorities. The research integrates the Supply Chain Operations Reference (SCOR) model with the Analytical Hierarchy Process (AHP) to evaluate performance and assign objective weights to key indicators. The analysis focuses on five critical workstations identified as major sources of waste. The results provide an objective performance score, identify key indicators requiring improvement, and offer prioritized recommendations to enhance efficiency. Findings show that indicators such as waiting time and facility layout efficiency still need improvement to reach an excellent performance level. The integration of SCOR and AHP effectively supports decision-making in determining improvement priorities, contributing to a more efficient and productive pulley manufacturing process. This study also offers a structured approach to performance evaluation in make-to-order systems, providing practical insights for decision-makers in Small and Medium Industries (SMIs).

**Keywords:** analytical hierarchy process, manufacturing industry, supply chain operations reference.

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## 1. Introduction

The industrial sector in Indonesia continues to grow in line with increasing export and domestic demand [1]. To face the challenges of global and domestic competition, companies need to measure supply chain performance to reduce costs [2]; [3], improve service quality [4], and meet customer needs appropriately [5]. Therefore, comprehensive supply chain performance analysis is essential to ensure operational effectiveness and efficiency [6].

In this context, performance measurement is an evaluation and strategic tool to identify areas for improvement [7]. This action is essential so companies can continue growing and excelling in competition [8]. Through performance evaluation, the supply chain can be continuously improved [9]; [10]. This is crucial because decisions in the supply chain directly impact a company's revenue, costs, and success [11].

This situation was also experienced by a company that manufactures 3-inch AS 22 mm B2 pulleys. Of the total 13 workstations, five critical workstations exhibited waste, particularly in waiting, defect rework, motion, overprocessing, and transport, resulting in a longer, less efficient production process. This situation highlights the importance of supply chain performance measurement so that companies can assess their production capabilities [12], evaluate the effectiveness of their existing systems [13], and determine the right priorities for improvement [14], [15].

Without conducting an SCM performance assessment, companies cannot identify weaknesses in their supply chains that affect stock fulfillment [16], product quality and production costs [17], and delivery accuracy [18]. This aligns with the need for companies to compete by developing better, faster, and more efficient products [19]. Supply chain performance evaluation is crucial for assessing operational efficiency and informing decision-making [20], thus requiring measurable parameters and indicators [21]. The Supply Chain Operations Reference (SCOR) can be used because it covers key performance aspects such as reliability, responsiveness, agility, cost, and asset efficiency [22]; [23]; [24]. Meanwhile, the Analytical Hierarchy Process (AHP) helps to weight the importance of each metric, enabling a more objective assessment [25]; [26]; [27]; [28].

Previous studies have applied SCOR and AHP to assess and improve supply chain performance in various sectors. The measurement results in the service sector [29] showed good categories, while some indicators still needed improvement in small and medium industries [16]. In the manufacturing sector, several aspects, such as responsiveness, have become top priority [30], while other companies recorded average performance, requiring improvement strategies for weak indicators [31]. In the construction sector, supply chain performance is limited by order fulfillment cycle time [32]. In the application of Sustainable Supply Chain Management (SSCM), eight Key Performance Indicators (KPIs) selected through AHP emphasize the integration of environmental, social, and financial aspects [1]. In the food sector, measurement designs using SCOR and AHP also involve halal metrics [28], while retail research compares several retailers to determine performance priorities [11]. In the distribution sector, SCOR and AHP-based measurement systems are utilized to monitor the procurement process for essential commodities [23]. Evaluations at other companies show good categories even though some metrics still require improvement [4].

Findings from previous studies confirm that although performance is often categorized as good, critical indicators always need improvement. Said et al. [33] identified critical stations or points based on risk probability, including traffic, people, weather, and materials, with a focus on operational risk mitigation. In contrast, this study applies SCOR and AHP to systematically measure supply chain performance in pulley production and prioritize improvements at each workstation, using KPIs driven by waste rather than generic indicators and adopting the SCOR Digital Standard.

This study measures supply chain performance in the pulley production process, which still experiences waste at several workstations. The study was conducted to determine how supply chain performance can be comprehensively measured using SCOR, how the weight of each performance metric is determined through AHP to obtain objective scores, and how the measurement results can be used to set improvement priorities at each workstation and increase production process efficiency.

## 2. Methods

This study aims to measure the priority of improvements in the make-to-order production process of pulley products, focusing on five critical workstations that show waste: waiting, defect/rework, motion, overprocessing, and transport. The research methodology was designed to align critical indicators with SCOR and determine the weight of each indicator through AHP, with the following stages:

### 2.1 Determination of critical indicators and SCOR mapping

The initial stage involved field observation and process mapping across 13 production workstations to identify areas generating the highest levels of waste. From this observation, five key categories of waste were selected and aligned with the corresponding SCOR performance attributes, as shown below:

- Waiting = responsiveness
- Defect/rework = reliability
- Motion = asset management/cost
- Overprocessing = cost/agility
- Transport = responsiveness/cost

The mapping was based on the conceptual impact of each waste category on SCOR performance dimensions, allowing a single waste type to be linked to multiple attributes when it affects multiple performance aspects.

### 2.2 Normalization of performance values

Performance indicator values are standardized using the Snorm De Boer so that all indicators are on the same scale and can be compared and combined into a total score. Data were collected over a one-month observation period. The normalization is expressed as:

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

where  $S_i$  represents the observed value,  $S_{min}$  is the minimum observed value, and  $S_{max}$  is the maximum.

### 2.3 Weighting of indicators using AHP

After critical indicators are entered into the SCOR matrix, performance weighting is performed using the AHP. Each indicator is compared with others using a priority scale to produce relative importance. The comparisons were based on expert judgments from three experts, including one production manager and two senior supervisors with more than 5 years of experience, and the judgments were aggregated using the geometric mean method.

Each indicator was compared against the others using a Saaty 1–9 scale, and the resulting pairwise comparison matrix was used to compute the eigenvector representing the priority weights. The consistency ratio (CR) was calculated as follows:

$$CR = \frac{CI}{RI} \quad (2)$$

CI is the Consistency Index, and RI is the Random Index.

A CR value below 0.10 was considered acceptable, indicating that the pairwise judgments were consistent and reliable.

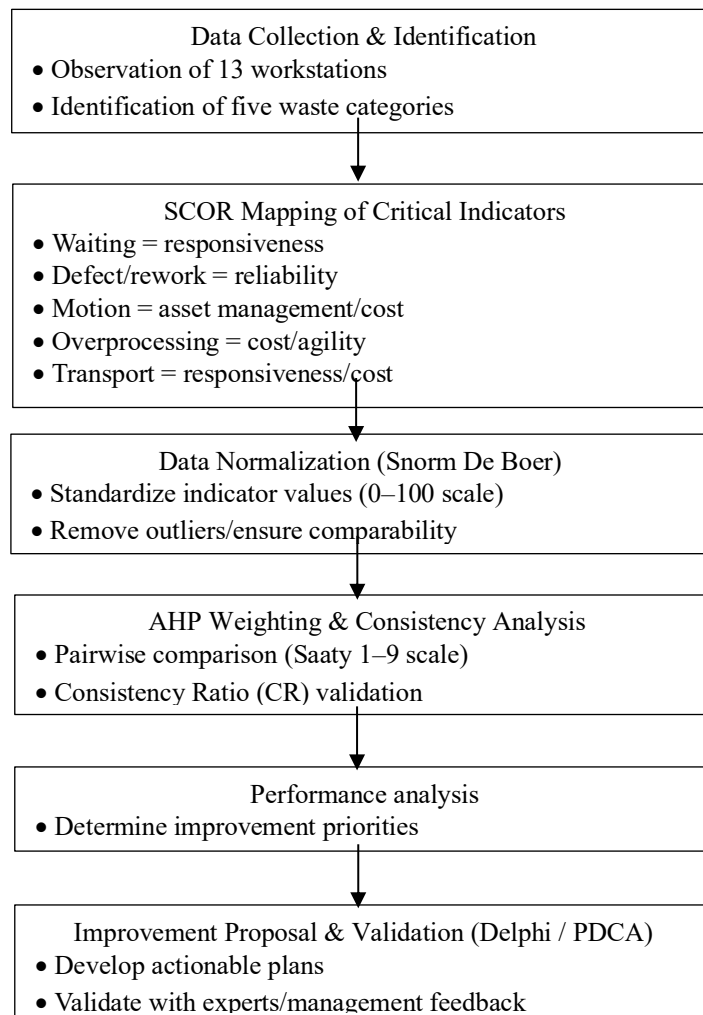
#### 2.4 Performance analysis

The total weights of critical indicators are analyzed to determine improvement priorities. Indicators with the highest weights are considered the most vital, while those below standard become the primary focus of improvement.

#### 2.5 Improvement proposals

Based on the weight analysis results, improvement proposals are formulated to increase production process efficiency and minimize waste at five critical workstations. The development of these improvement initiatives is based on the SCOR Digital Standard, which provides a structured framework consisting of six core processes: Plan, Order, Source, Transform, Fulfill, and Return [34]. This framework is used as a guideline to ensure that each improvement proposal aligns with the principles of best digital supply chain management.

Figure 1 presents the overall research flowchart, integrating the SCOR performance mapping and AHP-based weighting into a single systematic framework for performance assessment and improvement prioritization.



**Figure 1.** Research flowchart

### 3. Results and Discussion

#### 3.1. Reference Supply Chain Operations Mapping

The results of SCOR mapping, adjusted to the actual conditions, are presented in Table 1.

**Table 1.** SCOR Performance Matrix

| Main Process<br>Level 1 | Performance Indicators | Performance Attribute | Code   | Key Performance Indicators (KPI)                            |  |
|-------------------------|------------------------|-----------------------|--|---|--|
|                         |                        | Level 2               |  | Level 3   |  |
| Plan                    | Waiting                | Responsiveness        | RS.2.1   | Average waiting time between production processes           |  |
|                         |                        | Reliability           | RS.3.123                                       | Accuracy of production schedule against plan                |  |
| Source                  | Transport              | Reliability           | RL.2.1   | Consistency of daily output against target                  |  |
|                         |                        | Responsiveness        | RL.3.33  | Ratio of repeat setup time to total production time         |  |
|                         | Cost                   | Responsiveness        | RS.3.139                                       | Speed of material handling between departments              |  |
|                         |                        | Reliability           | CO.2.2   | Frequency of double movements                               |  |
| Make                    | Defect / Rework        | Reliability           | CO.3.9   | Efficiency of internal transport equipment usage            |  |
|                         |                        | Cost                  | RL.2.4   | Percentage of defective products against total production   |  |
|                         | Motion                 | Reliability           | RL.3.42  | Process completion time for repairs                         |  |
|                         |                        | Asset Management      | CO.2.3   | Number of additional working hours for rework               |  |
|                         | Overprocessing         | Cost                  | CO.3.12  | Material loss due to defective products                     |  |
|                         |                        | Agility               | AM.2.2   | Total distance traveled by operators per work cycle         |  |
| Responsiveness          |                        | AM.3.18               | Ratio of effective working time to moving time |   |  |
| Cost                    |                        | AM.3.27               | Work facility layout efficiency                |   |  |
| Deliver                 | Transport              | Reliability           | CO.3.13  | Ratio of non-value-added time to total process time         |  |
|                         |                        | Cost                  | CO.3.12  | Frequency of repeated repairs without added value           |  |
|                         | Agility                | Cost                  | CO.2.10  | Additional time per unit due to minor rework                |  |
|                         |                        | Responsiveness        | AG.2.2   | Number of additional processes due to specification changes |  |
|                         |                        | Reliability           | AG.2.12  | Efficiency of response to changes in the production process |  |
|                         |                        | Cost                  | RS.2.3   | Timeliness of delivery to the next stage                    |  |
|                         |                        | Responsiveness        | CO.2.4   | Number of transportation aids used                          |  |
|                         |                        | Cost                  | CO.3.14  | Efficiency of temporary storage space utilization           |  |

#### 3.2. Weighting with AHP

The next step is to weight the processes to determine the level of importance of each performance process using the AHP. The weight is considered valid if  $CR < 0.1$ . The weighting results are shown in Table 2.

**Table 2.** Process Weighting

| Process      | Plan        | Source       | Make        | Deliver     |
|--------------|-------------|--------------|-------------|-------------|
| Plan         | 1           | 3            | 0.5         | 2           |
| Source       | 0.33        | 1            | 0.25        | 0.5         |
| Make         | 2           | 4            | 1           | 3           |
| Deliver      | 0.5         | 2            | 0.33        | 1           |
| <b>Total</b> | <b>3.83</b> | <b>10.00</b> | <b>0.58</b> | <b>1.00</b> |

Table 3 shows the results of the normalization calculations used to determine the interprocess weight values.

**Table 3.** Interprocess normalization

| Process | Plan | Source | Make | Deliver |
|---------|------|--------|------|---------|
| Plan    | 0.26 | 0.30   | 0.24 | 0.31    |
| Source  | 0.09 | 0.10   | 0.12 | 0.08    |
| Make    | 0.52 | 0.40   | 0.48 | 0.46    |
| Deliver | 0.13 | 0.20   | 0.16 | 0.15    |

The table shows that the Make process has the highest value, indicating it is the most important process among the other. Table 4 shows the weighting and consistency calculations to determine the interprocess value.

**Table 4.** Eigenvector calculation

| Process | Total Weight Matrix | Eigen Vector | Matrix Multiplication | Eigen Value | $\lambda$ Max | CI   | RI   | CR   |
|---------|---------------------|--------------|-----------------------|-------------|---------------|------|------|------|
| Plan    | 1.11                | 0.28         | 1.12                  | 4.04        | 4.03          | 0.01 | 0.90 | 0.01 |
| Source  | 0.38                | 0.10         | 0.39                  | 4.02        |               |      |      |      |
| Make    | 1.86                | 0.47         | 1.89                  | 4.05        |               |      |      |      |
| Deliver | 0.64                | 0.16         | 0.65                  | 4.02        |               |      |      |      |

Based on the calculations in Table 4, a CR value of 0.01 was obtained. This indicates that the weighting between processes is consistent, as the CR value is less than 0.1. The next stage involved applying the AHP to obtain priority weights at each hierarchical level.

**Table 5.** Recapitulation of weighting with AHP

| Main Process | Weight Level 1 | Performance Attributes | Weight Level 2 | Code     | Weight Level 2 |
|--------------|----------------|------------------------|----------------|----------|----------------|
| Plan         | 0.28           | Responsiveness         | 0.75           | RS.2.1   | 0.07           |
|              |                |                        |                | RS.3.123 | 0.08           |
|              |                | Reliability            | 0.25           | RL.2.1   | 0.06           |
| Source       | 0.10           | Responsiveness         | 0.75           | RS.3.139 | 0.06           |
|              |                |                        |                | CO.2.2   | 0.04           |
|              |                | Cost                   | 0.25           | CO.3.9   | 0.05           |
|              |                |                        |                | RL.2.4   | 0.07           |
|              |                | Reliability            | 0.54           | RL.3.42  | 0.05           |
|              |                |                        |                | CO.2.3   | 0.04           |
| Make         | 0.47           | Asset Management       | 0.13           | AM.2.2   | 0.04           |
|              |                |                        |                | AM.3.18  | 0.05           |
|              |                |                        |                | AM.3.27  | 0.05           |
|              |                | Cost                   | 0.20           | CO.3.13  | 0.05           |
|              |                |                        |                | CO.3.12  | 0.03           |
|              |                | Agility                | 0.10           | CO.2.10  | 0.03           |
|              |                |                        |                | AG.2.2   | 0.03           |
| Deliver      | 0.16           | Responsiveness         | 0.75           | AG.2.12  | 0.04           |
|              |                |                        |                | RS.2.3   | 0.05           |
|              |                | Cost                   | 0.25           | CO.2.4   | 0.03           |
|              |                | CO.3.14                | 0.04           |          |                |

### 3.3. Snorm de Boer normalization

To obtain a more measurable priority value, the De Boer Snorm normalization process was carried out. The results of the De Boer Snorm normalization calculation are shown in Table 6.

**Table 6.** Snorm de Boer normalization

| Level 1 | Level 2          | KPI      | Actual Value | Min Value | Max Value | Snorm |
|---------|------------------|----------|--------------|-----------|-----------|-------|
| Plan    | Responsiveness   | RS.2.1   | 385          | 380       | 420       | 87.5  |
|         |                  | RS.3.123 | 2,150        | 2,100     | 2,400     | 83.3  |
|         | Reliability      | RL.2.1   | 98           | 80        | 100       | 86.7  |
| Source  | Responsiveness   | RL.3.33  | 190          | 180       | 300       | 91.7  |
|         |                  | RS.3.139 | 370          | 360       | 540       | 94.4  |
|         | Cost             | CO.2.2   | 6            | 5         | 12        | 85.7  |
|         |                  | CO.3.9   | 88           | 70        | 90        | 90.0  |
|         | Reliability      | RL.2.4   | 4            | 3         | 10        | 85.7  |
|         |                  | RL.3.42  | 150          | 145       | 208       | 92.1  |
| Make    | Cost             | CO.2.3   | 150          | 145       | 208       | 92.6  |
|         |                  | CO.3.12  | 12           | 10        | 35        | 92.0  |
|         |                  | AM.2.2   | 125          | 120       | 180       | 91.7  |
|         | Asset Management | AM.3.18  | 125          | 120       | 180       | 91.7  |
|         |                  | AM.3.27  | 90           | 70        | 95        | 80.0  |
|         | Cost             | CO.3.13  | 140          | 117       | 253       | 83.2  |
|         |                  | CO.3.12  | 01.05        | 1         | 5         | 89.7  |
| Deliver | Agility          | CO.2.10  | 116          | 114       | 165       | 96.1  |
|         |                  | AG.2.2   | 01.02        | 1         | 4         | 92.0  |
|         | AG.2.12          | 88       | 65           | 90        | 92.0      |       |
|         | Responsiveness   | RS.2.3   | 300          | 225       | 565       | 77.9  |
|         |                  | CO.2.4   | 01.01        | 1         | 2         | 89.0  |
|         | Cost             | CO.3.14  | 85           | 50        | 90        | 87.5  |

The Snorm de Boer normalization in Table 6 forms the basis for the final calculation of indicators in Table 7.

**Table 7.** Supply Chain Management Performance Values

| No    | KPI      | Snorm de Boer |   | Final Weight | Final SCM Score |
|-------|----------|---------------|---|--------------|-----------------|
|       |          | 1             | 2 | 1 x 2        |                 |
| 1     | RS.2.1   | 87.5          |   | 0.07         | 6.13            |
| 2     | RS.3.123 | 83.3          |   | 0.08         | 6.67            |
| 3     | RL.2.1   | 86.7          |   | 0.06         | 5.20            |
| 4     | RL.3.33  | 91.7          |   | 0.05         | 4.58            |
| 5     | RS.3.139 | 94.4          |   | 0.06         | 5.67            |
| 6     | CO.2.2   | 85.7          |   | 0.04         | 3.43            |
| 7     | CO.3.9   | 90.0          |   | 0.05         | 4.50            |
| 8     | RL.2.4   | 85.7          |   | 0.07         | 6.00            |
| 9     | RL.3.42  | 92.1          |   | 0.05         | 4.60            |
| 10    | CO.2.3   | 92.6          |   | 0.04         | 3.70            |
| 11    | CO.3.12  | 92.0          |   | 0.06         | 5.52            |
| 12    | AM.2.2   | 91.7          |   | 0.04         | 3.67            |
| 13    | AM.3.18  | 91.7          |   | 0.05         | 4.58            |
| 14    | AM.3.27  | 80.0          |   | 0.05         | 4.00            |
| 15    | CO.3.13  | 83.2          |   | 0.05         | 4.16            |
| 16    | CO.3.12  | 89.7          |   | 0.03         | 2.69            |
| 17    | CO.2.10  | 96.1          |   | 0.03         | 2.88            |
| 18    | AG.2.2   | 92.0          |   | 0.03         | 2.76            |
| 19    | AG.2.12  | 92.0          |   | 0.04         | 3.68            |
| 20    | RS.2.3   | 77.9          |   | 0.05         | 3.90            |
| 21    | CO.2.4   | 89.0          |   | 0.03         | 2.67            |
| 22    | CO.3.14  | 87.5          |   | 0.04         | 3.50            |
| Total |          |               |   |              | 94.49           |

Based on the supply chain management performance scores in Table 7, the final SCM score was 94.49, placing it in the Excellent category. Scores of 70-89 are classified as Good and  $\geq 90$  as Very Good, following the commonly used SCM performance evaluation criteria in the SCOR framework. Several performance indicators recorded scores below 90 and therefore remained in the good category. The lower scores are likely due to unbalanced workstation load, suboptimal material flow, and delays in certain processes, highlighting opportunities to apply lean manufacturing principles to reduce waste. Several high-weight KPIs showed lower values, indicating priority areas for improving SCM performance.

Compared with previous studies, this achievement represents a significant improvement. The survey by Kusrini et al. [19] reported a final score of 70.94, while Kusrini et al. [8] obtained a score of 77.89. The studies by Susanto et al. [31] and Prasetyaningsih et al. [17] reported scores of 69.983 and 68.231. Furthermore, Hasibuan et al. [30] found that supply chain performance fell within the good range (50–100), and Marzuqi et al. [32] reported a result of 84.83. The SCM score in this study, 94.49, is higher than all previous studies, suggesting that implementing the SCOR process and prioritizing improvements using AHP can enhance supply chain effectiveness. These findings also highlight the potential benefits of lean manufacturing and digital supply chain integration. Indicators scoring below 90 remain priorities for further improvement, as shown in Table 8.

**Table 8.** Recommendations for improvement

| Performance Indicators | Code     | KPI   | Causes  | Improvement (SCOR DS)   |
|------------------------|----------|---|---|---|
| Waiting                | RS.2.1   | Average waiting time between production processes | The schedule between processes is not synchronized, causing material to pile up at the next work station. | Integrate digital scheduling systems between processes to synchronize workflows.                  |
|                        | RS.3.123 | Accuracy of production schedule against plan      | Delays in raw materials and ineffective coordination between departments.                                 | Implementing an integrated scheduling system and coordination briefing at the start of the shift. |
| Performance Indicators | Code     | KPI   | Causes  | Improvement (SCOR DS)   |

|                |         |   |  |   |
|----------------|---------|---|--|---|
|                | RL.2.1  | Consistency of daily output against target                | Machine performance is unstable and operators are not yet proficient in their skills.          | Performing scheduled preventive maintenance and improving operator skills through regular training. |
| Transport      | CO.2.2  | Frequency of double movements                             | The layout of the work area is inefficient, resulting in repeated material transfers.          | Redesign the layout based on material flow and implement kanban to reduce unnecessary movement.     |
| Defect/Rework  | RL.2.4  | Percentage of defective products against total production | Casting pressure is inconsistent.  | Performing periodic machine calibration and process control to prevent recurring defects.           |
| Motion         | AM.3.27 | Work facility layout efficiency                           | Machine and storage area placement does not follow the production process sequence.            | Reorganize facilities based on process sequence (lean flow).  |
| Overprocessing | CO.3.13 | Ratio of non-value-added time to total process time       | Setup and inspection activities are performed repeatedly without adding value to the product.  | Standardization of work procedures to eliminate non-value activities.                               |
|                | CO.3.12 | Frequency of repeated repairs without added value         | Repairs are made without proper root cause analysis.   | Implementing Root Cause Analysis and documenting each corrective action.                            |
|                | RS.2.3  | Timeliness of delivery to the next stage                  | The material queuing system is not yet optimal.  | Using a visual alarm system between workstations to streamline material flow.                       |
| Transport      | CO.2.4  | Number of transportation aids used                        | The use of tools is not well regulated, often resulting in waiting for turns.                  | Schedule the use of transportation to avoid queues.   |
|                | CO.3.14 | Efficiency of temporary storage space utilization         | The arrangement of semi-finished products is disorderly and the storage system is inefficient. | Implementing the FIFO system and using vertical racks to optimize space.                            |

Improvement efforts focus on enhancing the efficiency of the pulley production process through layout optimization, quality control, and process-scheduling synchronization to improve overall system performance.

#### 4. Conclusion

This study provides a comprehensive overview of the effectiveness of pulley production processes utilizing a KPI-based measurement approach. The evaluation results show that several aspects, including waiting time, layout efficiency, and rework frequency, still require improvement to achieve optimal performance levels. Implementing improvements in these areas is expected to improve process flow, reduce production costs, and strengthen the overall reliability of the production system. The weakness of this study lies in the limited data, which covers only a specific period of time and does not account for external factors such as market demand fluctuations or changes in machine conditions. Additionally, the subjectivity of expert judgments and the single case scope may limit generalizability. For further research, it is recommended to collect long-term data and to consider integrating analytical methods, including machine learning, to predict production performance and optimize real-time decision-making.

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#### Declaration of AI and AI-assisted technologies in the writing process

During the preparation of this work, the author(s) used Gemini and Grammarly to assist in language editing and improving the readability of the manuscript. The authors reviewed and revised all generated content and take full responsibility for the final version of the manuscript.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

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