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Scientific Articles

Inventory Optimization of Work Tool Availability at an Automotive Workshop

Optimasi Persediaan untuk Ketersediaan Perkakas Kerja di Bengkel Otomotif

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Abstract

Automotive workshops commonly face inefficiencies in special-tool availability due to manual and non-transparent tracking systems. This study addresses this challenge by examining the impact of limited tool quantities on operational performance, particularly the low average service level (86.18% vs. the 95% target). This study is among the first to integrate a digital tool management system with quantitative inventory-optimization methods, i.e., Safety Stock and Cost-Benefit Analysis (CBA), in an automotive workshop context. Borrowing-transaction records collected over 60 days were analyzed to identify critical tools with the highest demand variability. Although most tools achieved full availability, 15 high-demand tools contributed to reduced overall service level and were therefore prioritized in the optimization process. Application of Safety Stock analysis recommended ideal inventory quantities, while CBA revealed diminishing-return thresholds, preventing unnecessary investment. Key improvements include increasing service level from 71.27% to 99.51% and enhancing cost efficiency to 89.04%. The combined digital recording system and quantitative optimization framework have proved highly effective in improving tool availability and reducing operational costs. This approach offers a scalable model for automotive workshops seeking to enhance efficiency and sustainability through data-driven tool-management strategies.

Keywords: *Automotive workshop, Cost-benefit analysis, Inventory optimization, Safety stock.*

Abstrak

Bengkel otomotif umumnya menghadapi ketidakefisienan dalam ketersediaan perkakas khusus akibat sistem pencatatan yang masih manual dan kurang transparan. Penelitian ini membahas permasalahan tersebut dengan mengkaji dampak keterbatasan jumlah perkakas terhadap kinerja operasional, khususnya rendahnya tingkat layanan rata-rata (86,18% dibandingkan target 95%). Penelitian ini merupakan salah satu yang pertama mengintegrasikan sistem manajemen perkakas digital dengan metode optimasi persediaan kuantitatif, yaitu Safety Stock dan Cost-Benefit Analysis (CBA), dalam konteks bengkel otomotif. Data transaksi peminjaman perkakas yang dikumpulkan selama 60 hari dianalisis untuk mengidentifikasi perkakas kritis dengan variabilitas permintaan tertinggi. Meskipun sebagian besar perkakas memiliki tingkat ketersediaan penuh, sebanyak 15 perkakas dengan permintaan tinggi terbukti menjadi penyebab utama penurunan tingkat layanan secara keseluruhan, sehingga diprioritaskan dalam proses optimasi. Penerapan analisis Safety Stock menghasilkan rekomendasi jumlah persediaan ideal, sementara CBA mengungkap adanya ambang batas diminishing return yang mencegah investasi berlebih pada perkakas. Hasil utama menunjukkan peningkatan tingkat layanan dari 71,27% menjadi 99,51% serta peningkatan efisiensi biaya hingga 89,04%. Integrasi sistem pencatatan digital dengan kerangka optimasi kuantitatif terbukti sangat efektif dalam meningkatkan ketersediaan perkakas dan menurunkan biaya operasional. Pendekatan ini menawarkan model yang skalabel bagi bengkel otomotif untuk meningkatkan efisiensi dan keberlanjutan melalui strategi manajemen perkakas berbasis data.

Keywords: Bengkel otomotif, Cost-benefit analysis, Optimasi persediaan, Safety stock.

1. Introduction

The company discussed in this study is an enterprise focused on the automotive sector, specifically on the sale and maintenance and repair services for the Mercedes-Benz brand. To maintain its commitment to service quality, time efficiency, and professionalism, the firm has faced significant challenges in managing the tools mechanics need to perform their tasks, particularly specialized tools essential to maintaining modern Mercedes-Benz cars. In line with trends in the automotive industry, the increasing technical complexity of vehicles—especially with the rise of EVs—demands greater accuracy and greater availability of specialized tools. (Ramalingam et al., 2021). Currently, the workshop's inventory management system is still manual, relying on handwritten records and coins as markers of tool usage. This method does not provide real-time status or historical traceability, leading to frequent work delays and increased pending costs. (Ariana & Candraningrat, 2025; Maheshwari et al., 2025). Similar problems in manual systems are also reported in the energy and aviation sectors, leading to data inaccuracies, tool loss, and operational inefficiencies. (Castilla, 2022; Fa'iz et al., 2025). More broadly, delays and errors in inventory management affect service quality and increase unnecessary operational costs. (Allal et al., 2021; Rahmadani & Arvitrida, 2025).

To address these issues, an integrated Tool Management System (TMS) becomes necessary. TMS covers inventory tracking, tool usage monitoring, maintenance scheduling, and tool-need forecasting based on historical data (Xiucai et al., 2021). Previous works using cloud-based systems, RFID, and mobile applications have demonstrated significant improvements in data accuracy, automation, and transparency. (Castilla, 2022; Chen et al., 2022; Fa'iz et al., 2025). For instance, long-range RFID can identify tools and users up to 150 cm and increase work discipline. (Fa'iz et al., 2025), while QR-based mobile systems enhance traceability and security (Castilla, 2022). Nonetheless, these studies primarily emphasize digital automation and tracking accuracy, rather than comprehensive inventory optimization.

Despite advancements in digital tool management, a clear research gap remains. Previous studies have not thoroughly integrated quantitative inventory optimization, such as Safety Stock. (Kirmizi et al., 2024) or spare-part-based maintenance analytics (Rahmadani & Arvitrida, 2025)—with economic feasibility evaluation, such as Cost-Benefit Analysis (CBA), which has been commonly applied in construction and asset management (Vaughan et al., 2013). There is a lack of research on combining digital tool tracking, Safety Stock calculations, and CBA-based economic evaluation within the context of automotive workshop operations. Furthermore, links to sustainability—through energy efficiency, emission reduction, logistics optimization, and circular economy strategies—have been explored in manufacturing and workshop environments. (Abdelaoui et al., 2023; Allal et al., 2021; Luan et al., 2023; Momeni et al., 2025; Yusuf et al., 2021) However, not explicitly connected to special tool availability in automotive after-sales services.

Therefore, this study aims to develop an integrated solution that combines internal digital TMS data with quantitative inventory optimization (Safety Stock) and an economic evaluation framework (CBA) to enhance tool availability, minimize delays, and reduce operational costs at the workshop. This research seeks to fill the identified gap by demonstrating how digital recording and analytical inventory optimization can jointly improve service efficiency, sustainability performance, and managerial decision-making in automotive workshops. As emphasized by Okwelle & Kilechukwu (2022), The structured organization, planning, coordination, and control of workshop tools are essential to ensuring long-term operational excellence.

2. Methods

Two principal approaches are used: the Inventory Optimization – Safety Stock and the Cost-Benefit Analysis (CBA) simulation, which are used to assess tool needs while managing future demand uncertainty. The flow diagram of the methods is shown in Figure 1.

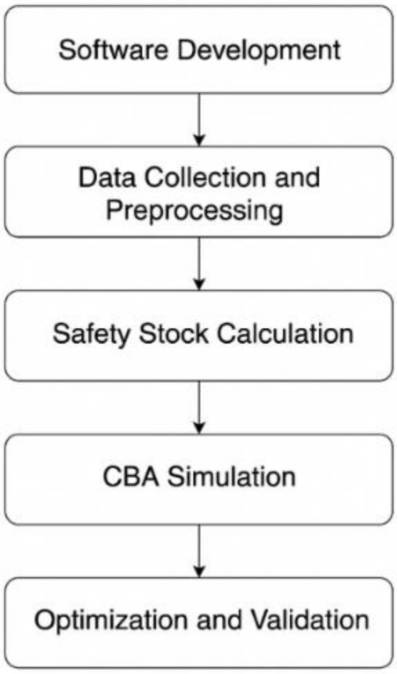

Figure 1. Research workflow illustrating the sequential process from software development, data preprocessing, safety stock computation, CBA simulation, optimization, and validation.

The first stage involved developing an internal tool management software tailored to workshop operations. The system automates the borrowing–returning workflow and stores real-time transaction logs as the primary analytical dataset. To reduce narration and improve clarity, the software stack is summarized in Table 1.

Table 1. Software Stack and Functions

Component	Technology	Function
Backend	PHP	Borrow–return logic, API, data validation
Database	PHPMyAdmin (MySQL)	Storage of tool profiles & transactions
Frontend	HTML/CSS	User interface for mechanics & admins
Local Server	XAMPP	Hosting and local deployment

2.1. Data Collection

Data was gained from transaction records of special tools borrowed by mechanics during a defined observation period. The main variables used in the analysis include:

- Average of daily demand (μd): frequency of tool borrowings per day.
- Standard deviation of daily demand (σd): variability of daily demand, used to quantify the uncertainty.
- Lead time: time required for tool procurement or replacement.
- Service level: targeted percentage of demand that must be fulfilled without stockouts.
- Borrowing duration: the mean time of the tool being borrowed, to provide insight into the usage patterns of tools.

The significance of these variables aligns with the literature in inventory management and service level optimization, which highlights the effects of demand variability and lead time on safety stock evaluation. (Seyedan et al., 2023).

2.2. Analysis of Preliminary Data

The collected data were subjected to descriptive statistical analysis to provide an initial overview of time-varying demand patterns, usage distributions, and their variations. Such descriptive analysis is a standard procedure in inventory information systems, enabling the identification of early trends before optimization. (San-José et al., 2022).

2.3. Pre-Processing of Data

This stage comprises preliminary calculations before determining safety stock. The procedure includes evaluating the average borrowing frequency of a special tool over a given period and calculating its borrowing standard deviation.

2.4. Calculation of Safety Stock

Safety stock is calculated to determine the level of reserve inventory required to accommodate both demand variability and lead-time uncertainty. The calculation is based on the average daily demand, standard deviation, targeted service level, and lead time.

$$SS = Z \times \sigma_d \times L^{0.5} \quad (1)$$

SS: Safety Stock
Z: factor (value related to service level or expected level of service)
σ_d: standard deviation of daily demand (variability in demand)
L: lead time (time of delivery)

2.5. Determination of the Total of Initial Inventory

After the safety stock value is obtained, the total initial inventory is calculated by summing the average daily demand and the safety stock. This value represents the minimum number of tools required to meet mechanics' needs, in accordance with the service level target. The equation defining the total of initial inventory is as follows:

$$Total\ Inventory = \mu_d + SS \quad (2)$$

The average daily demand (μd) reflects the routine need for tools. At the same time, the safety stock provides an additional buffer to account for unexpected events such as demand surges or delays in tool procurement.

2.6. Simulation of the Cost-Benefit Analysis (CBA)

CBA is performed to evaluate the efficiency of tool provision through various inventory scenarios. This analysis considers the following factors:

- Cost for pending/hour: financial loss is incurred when mechanics are unable to work due to tool shortages.
- Average pending hours: average of downtime per type of special tool.
- Price to invest: procurement cost of buying new tools.
- Maintenance fee: tool maintenance cost per period.
- Assumed year to use: maximum service lifespan of the tool before its replacement.

CBA is a requisite technique in comparing direct costs and operational benefits. For that reason, the approach has been widely applied across various fields, including healthcare programs. (Gentili et al., 2022) and manufacturing (Teng et al., 2022). In previous studies, methodology was the central point in assessing the efficiency of implementing the mentioned activities. Especially in the works by Teng et al. (2022), the simulation results indicate the optimal point, i.e., the number of tools at which additional investment no longer yields a significant improvement in service level (diminishing returns).

2.7. Inventory Optimization

The final step involves determining the optimal inventory level by comparing the results of the CBA simulations across various scenarios. The optimal level is selected to achieve the desired service level at minimum cost. This multi-objective optimization concept has also been applied to the design of low-carbon workshop layouts and reverse supply chains, where balancing cost, performance, and sustainability is indispensable.

2.8. System Validation

To address system validation, this study includes user testing. Mechanics and workshop supervisors performed trial tool-borrowing tasks using the new software. These steps ensure that the digital recording system not only collects accurate data but is also operationally feasible for daily workshop activities.

Table 2. Studies into the significance of digitizing inventory systems through advanced technologies

Aspects being compared	**Authors**			
	Xiucai et al. (2021)	Chen et al. (2022)	Castilla (2022)	Present researchers
Application field	Equipment business management	Electric tools in power grid production	Aviation equipment and tools	Automotive workshop tools
Technology	Cloud platform, OPC UA, distributed system framework	Indoor positioning, integrated intelligent workstation, RFID	Mobile application, QR code system	CSS, HTML, PHP, PHP MyAdmin, XAMPP
Tool management	Hierarchical functional software architecture, integrated business process, and real-time equipment state monitoring	Access control, movement tracking, integrated management of tools, staff, and operations; real-time inventory tracking	Asset tracking, mobile-optimized inventory management, survey-informed system design	Database-driven inventory tracking, with manual logs digitized into an internal software system.
Importance of digitizing inventory systems	High: enabling predictive maintenance and decision-making, automation improvement	High: efficiency improvement, complete life-cycle management, real-time updates	Medium-High: accuracy improvement, best practices support, secure tracking	Medium: facilitating data storage and retrieval, reducing human error
Advantages	Real-time monitoring, scalable, integrates with business processes, and predictive analytics.	Real-time tracking, automated registration, regional positioning, and an integrated system for staff and operations	Portable, user-friendly, supports field updates, and has low infrastructure requirements	Low cost, easy to implement, digitalization of existing records
Limitations	Requiring network stability, higher software complexity, and a strong need for technical expertise	High initial cost, complexity in setup, and requiring RFID infrastructure	Limited automation, relying on manual scanning, may not provide real-time location tracking	Limited real-time capabilities, less automation, smaller scalability, and less advanced technology

3. Results and Discussion

3.1. Software Development and Data Recordings

Software development represents an initial step towards optimizing the data recording process, which is currently performed manually through handwritten logs. The software developed in this study is an internal application designed exclusively for Tool Room staff. It uses PHP as the backend language, HTML for the front-end, CSS for styling, and PHPMyAdmin for database management. In this environment, the XAMPP Control Panel serves as a bridge between the Apache server and MySQL. This outcome aligns with prior studies that highlight the importance of digitizing inventory systems using advanced technologies, such as cloud platforms. (Xiucai et al., 2021), RFID (Chen et al., 2022), and QR-code–based mobile applications (Castilla, 2022), which can enhance accuracy, efficiency, and the security of tool management. A comparison of the present work with earlier studies by Xiucai et al. (2021), Chen et al. (2022), and Castilla (2022) is summarized in Table 2.

From Table 2, it is evident that all the studies focus on digitizing inventory management, improving accuracy, supporting decision-making, and efficiently tracking tools. The differences among the works appear in the level of technology and automation. Advanced systems (RFID, cloud platforms) provide real-time tracking and integration, while moderate systems (mobile apps) improve accessibility and security but have less automation. Moreover, the basic systems (PHP/MySQL) used in this study mainly digitize records but have limited real-time capabilities. The comparison shows that digitizing inventory enhances efficiency and control. More importantly, advanced technologies utilized in the earlier studies of Chen et al. (2022) and Xiucai et al. (2021) can deliver higher automation, real-time monitoring, and predictive capabilities, while simpler solutions (Castilla, 2022; present work) They are more affordable and easier to implement. The choice, thus, depends on scale, cost, and operational complexity.

3.2. Preliminary Data Analysis

Figure 2 presents the number of workshop tool borrowing records and the average of tool-daily borrowing transactions by mechanics at the automotive workshop within a 60-day observation period. From the figure, over the period of transaction records, the average daily borrowing is 70, with a minimum of 68 and a maximum of 73 special tools borrowed by mechanics daily. The number of transactions is highly dependent on workshop conditions, varying according to fluctuations in customer demand, ranging from busy days with high service requests to quieter days with fewer service requests. Nevertheless, throughout the 60 days, the workshop environment remained relatively stable, with no fluctuations in the volume of borrowed tools.

Figure 3 illustrates fluctuations in service level and the averages of daily and targeted service levels in the workshop's tool room. The average daily service level in the room is 86.18%. This number remains below the expected target of 95%. To optimize the availability of workshop tools and achieve the desired target, it is essential to identify which special tools contribute to the overall daily service level falling below 95%.

A few special tools fall into a minority cluster with a destitute service level of less than 95% and their borrowing frequencies are recapitulated in Figure 4. From the figure, special tools in the minority group, i.e., the specified tools on the x-axis with the suboptimal service level, exhibit higher borrowing frequencies than other workshop tools in the non-minority category. Such a phenomenon is an anomaly. Conversely, many other special tools in the majority class with a 100% service level have lower borrowing frequencies than their counterparts in the minority class. This inherently minimizes the occurrence of pending transactions. Furthermore, daily service levels falling below the targeted average are primarily driven by a high incidence of pending transactions associated with frequently borrowed special tools, such as Tools 190, 63, and 48. Such a condition corroborates prior findings that imbalances in tool demand can lead to bottlenecks, even when the majority of inventory remains within safe thresholds (Kirmizi et al., 2024).

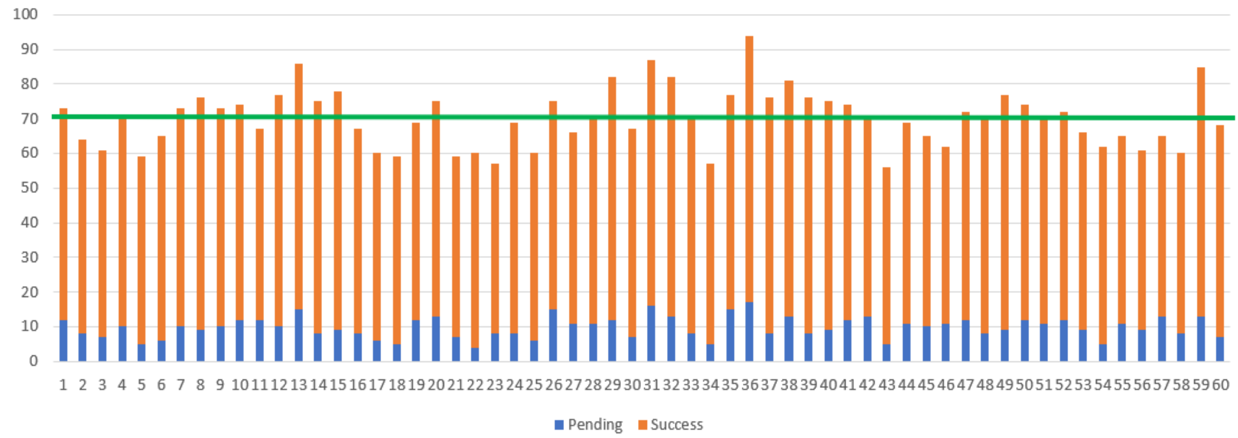

Figure 2. Number of workshop tool borrowing records and the average number of workshop tools daily borrowed by mechanics

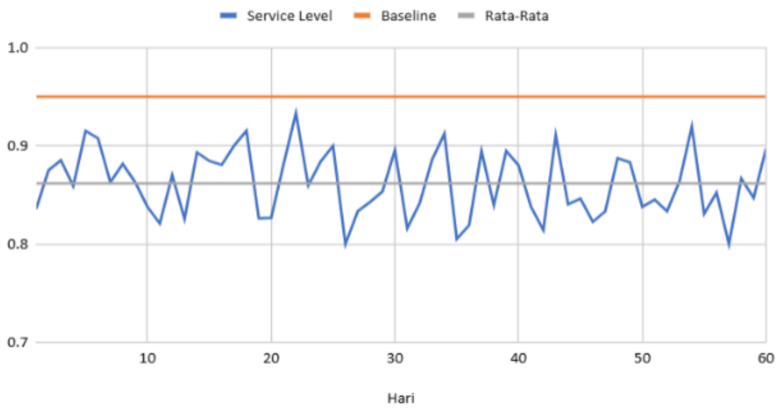

Figure 3. Fluctuating service level and the averages of baseline and initial service levels

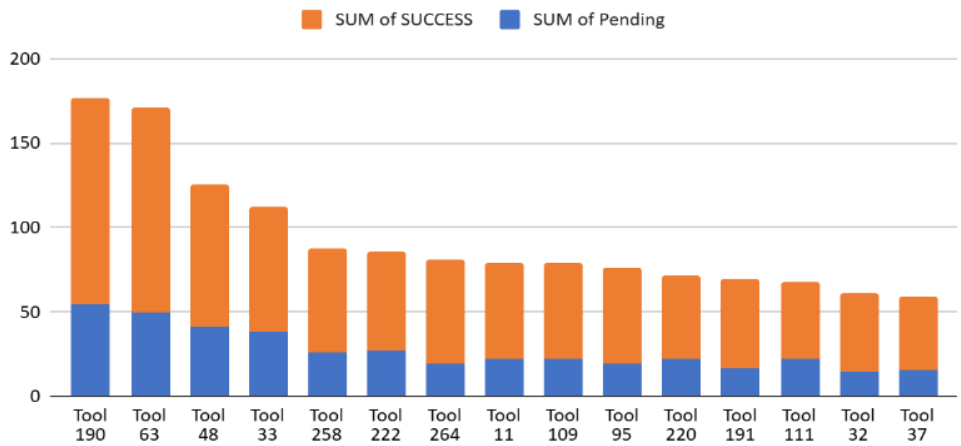

Figure 4. Special tools with higher borrowing frequencies

The findings are strengthened by the data in Figure 5, which show that the service levels of special tools with higher borrowing frequencies are indeed below the baseline service level, i.e., less than 75% on average. Subsequently this serves as the basis for focusing optimization of the number of special tools on the 15 workshop tools with higher borrowing frequencies, which are Tool 190, Tool 63, Tool 48, Tool 33, Tool 258, Tool 222, Tool 264, Tool 11, Tool 109, Tool 95, Tool 220, Tool 191, Tool 111, Tool 31, and Tool 37.

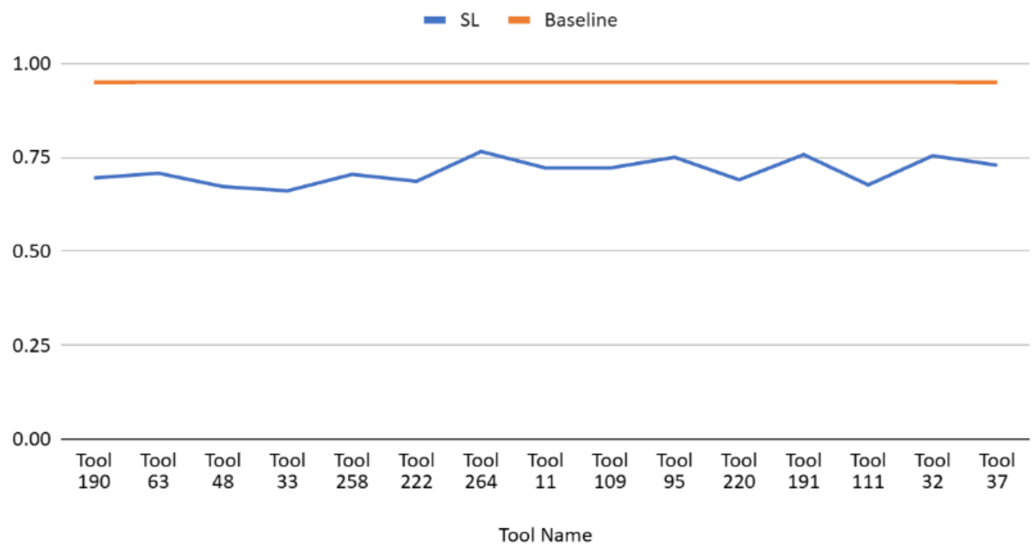

Figure 5. Comparison between the baseline service level (SL) and SLs of 15 special tools with higher borrowing frequencies

Table 3. Calculation of the safety stock and the ideal inventory for 15 special tools with higher borrowing frequencies

Tool Number	#Success	#Pending	Total Transaction	%SL	Tool Quantity	Mean	Stdev	Safety Stock	Ideal Inventory
190	123	54	177	69.5%	1	3	1.62	3	6
63	121	50	171	70.8%	2	3	1.87	4	7
48	84	41	125	67.2%	2	2	1.38	3	5
33	74	38	112	66.1%	1	2	1.75	3	5
258	62	26	88	70.5%	2	1	1.65	3	5
222	59	27	86	68.6%	1	1	1.45	3	4
264	62	19	81	76.5%	2	1	1.40	3	4
11	57	22	79	72.2%	2	1	1.41	3	4
109	57	22	79	72.2%	1	1	1.49	3	4
95	57	19	76	75.0%	1	1	1.45	3	4
220	49	22	71	69.0%	1	1	1.67	3	4
191	53	17	70	75.7%	1	1	1.47	3	4
111	46	22	68	67.6%	1	1	1.21	2	4
32	46	15	61	75.4%	1	1	1.33	3	4
37	43	16	59	72.9%	2	1	1.30	3	4

3.3. Calculations of Safety Stock and Ideal Stock

Following the preliminary data analysis, the safety stock (SS) and the ideal stock (i.e., the total of the initial inventory) are to be calculated. The safety stock can be quantified using Equation 1, after the 15 special tools with service levels remarkably below 95% were identified. In this way, with a Z-value of 1.96 and the standard deviation varying with each special tool—calculated with the Excel formula "=STDEV(Data Demand Range)" the safety stock for each special tool was obtained and summarized in Table 3. Afterwards, when the safety stock for each special tool is already available, the ideal stock is calculated. This can be achieved using Equation 2 and its values; the ideal inventory values are tabulated in Table 3.

From Table 3, it is evident that the total of ideal inventory exceeds the number of special tools currently available at the automotive firm. Theoretically, a larger number of specialized tools may help maintain service levels and reach the optimal target of 95%. However, this could be a waste of the corporation's resources to invest in the recommended values for the ideal inventory, even if the buffer special tool stock is not optimally utilized. The findings confirm the trend observed by Arasteh (2022), who aimed to determine optimal stock quantities and link inventory decisions to financial performance. Comparisons with Arasteh's (2022) study are presented in Table 4.

Table 4. Comparisons of this present study with that of Arasteh (2022)

Areas of comparison	Arasteh (2022)	The present study
Cost	Minimizing safety stock costs, developing models to reduce holding costs while ensuring service, and discussing overall cost efficiency through network optimization.	Using CBA to prevent over-investment and improve cost efficiency (to 89.04%); cost reduction is demonstrated through empirical results.
Inventory optimization	Addressing inventory optimization through a specified problem formulation, approximation algorithms, and computational testing to optimize placement throughout the supply chain network.	Applying quantitative inventory-optimization methods (Safety Stock + CBA) combined with digital tracking to improve operational tool availability.
Safety Stock	Focusing on determining *where* to place safety stock across a multi-stage or two-layer supply chain, including a nonlinear model to compute appropriate safety stock levels.	Employing Safety Stock analysis to determine ideal quantities for high-demand tools with variable usage, and directly applying safety stock calculations to improve tool availability.
Service level	Highlighting the need to maintain customer service capability, but not quantifying service-level improvements. The focus is more on the structural optimization of safety stock.	Measuring service level and improving service level (from 71.27% to 99.51%). Service level is a direct objective of the optimization.

As shown in Table 4, both studies (Arasteh, 2022; present authors) position safety stock as a central mechanism for improving operational reliability. Arasteh (2022) Examined safety-stock placement across multi-stage supply chains, while the present study applies safety-stock calculations to ensure tool availability in an automotive workshop. Despite their different contexts, each paper views safety-stock determination as essential to maintaining smooth operations and mitigating demand variability. Both the current research and Arasteh's (2022) work also emphasize cost efficiency as a key performance outcome. Minimizing safety-stock holding costs across a network is the focus of Arasteh (2022), whereas the present work demonstrates improved cost efficiency through structured investment decisions and avoidance of unnecessary tool purchases. In each case, the optimization methods are linked to tangible financial benefits. Finally, both works offer practically oriented solutions. The research of Arasteh (2022) Has provided models and approximation strategies to guide real-world supply-chain design, while this study demonstrates a functioning, data-driven framework implemented in a workshop setting. Each study, therefore, combines analytical rigor with operational relevance.

3.4. Cost-Benefit Analysis and Validation of Ideal Stock

A Cost-Benefit Analysis (CBA) was conducted to determine the optimal number of special tools. The three primary variables in the CBA were "Cost per Pending Hour" (the cost of having mechanics wait until the required special tool is borrowed), "Price to Invest," and "Maintenance Fee." Each tool quantity scenario (1-10 units) was analysed to calculate the total monthly cost, which is the sum of the three costs. Additionally, the service level for each scenario was evaluated to assess the extent to which demand could be met with a certain number of tools. Using Equation 2, two additional variables were also included in this calculation: "Average Pending Hour" and "Assumed Years to Use." The variable "Average Pending Hour" ranged from 0.5 to 3 hours, with a modus value of 3 hours, while the variable "Cost per Pending Hour" was set to IDR 91,666.67 per hour, and the variable "Assumed Years to Use" was fixed at 5 years for all tools. The Cost-Benefit Analysis was certainly not manually managed; instead, it was automatically performed in Excel.

An example of analysis is explained for Tool 63. As depicted in Figure 6, increasing the quantity of a special tool does not always lead to savings in pending costs. As shown by the blue line, the pending cost initially decreases significantly as the tool quantity increases from 2 to 5. Still, this is not the case after the tool quantity of 5, with a constant pending cost of Rp. 0 until the tool quantity exceeds 10. To the total cost, the trend is different. Once the total cost reaches its minimum at a tool quantity of 5, continually increasing the special tool quantity results in higher expenditure costs owing to larger investment and maintenance expenses. Therefore, CBA is implemented to determine detailed expenditure costs and the corresponding service level for a given quantity (n) of special tools.

The sensitivity analysis shows that increasing the tool quantity from 2 to 5 units improves the service level from 70.80% to 100%, reflecting a 29.2% absolute (41.2% relative) increase, while reducing the total monthly cost from Rp 2,641,666.67 to Rp 875,000.00, a 66.9% cost reduction. Within this range, each added tool contributes an average of 13.7% service-level gain and 22.3% cost reduction, demonstrating that insufficient inventory creates disproportionately high pending costs. This nonlinear behavior confirms that optimizing tool quantity has a substantial positive impact when addressing under-stocking conditions.

Beyond five tools, the service level remains at 100% (0% further improvement), while total cost increases from Rp 1,000,000.00 to Rp 1,625,000.00, a 62.5% rise solely due to higher maintenance and investment expenses. The negative sensitivity—about a 12–14% increase in cost per additional tool—indicates diminishing returns, where more tools add cost without operational benefit. These patterns suggest that even with moderate variations in demand variability or lead time (±10–15%), the optimal inventory remains stable around 4–5 units, demonstrating the robustness of the optimization outcome.

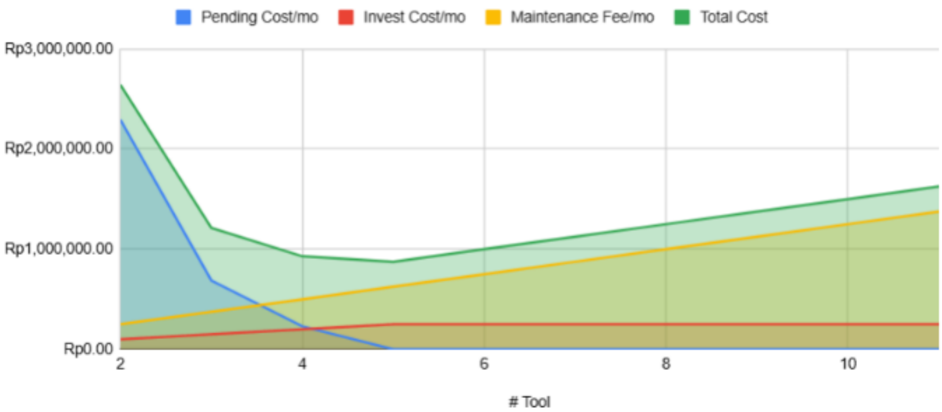

Figure 6. Chart for Tool 63 (tool quantity vs total cost)

From Table 5, when Tool 63 is stocked at five units or more, no pending costs occur, as the service level reaches 100%, indicating no conflicts in tool borrowing among mechanics. If the quantity of Tool 63 exceeds five units, as shown in Table 5, the company's costs would also increase. Such a situation indeed aligns with the theory of diminishing returns in inventory management, which holds that additional investment does not always yield proportional benefits. (Allal et al., 2021; Vaughan et al., 2013). The same calculation applies to the other special tools.

Table 5. Recapitulation of cost spending per month for Tool 63

Tool Quantity	%SL	Pending Cost/month	Investment Cost/month	Maintenance Fee/month	Total Cost
2	70.80%	Rp 2,291,666.67	Rp 100,000.00	Rp 250,000.00	Rp 2,641,666.67
3	91.20%	Rp 687,500.00	Rp 150,000.00	Rp 375,000.00	Rp 1,212,500.00
4	97.10%	Rp 229,166.67	Rp 200,000.00	Rp 500,000.00	Rp 929,166.67
5	100.00%	Rp 0.00	Rp 250,000.00	Rp 625,000.00	Rp 875,000.00
6	100.00%	Rp 0.00	Rp 250,000.00	Rp 750,000.00	Rp 1,000,000.00
7	100.00%	Rp 0.00	Rp 250,000.00	Rp 875,000.00	Rp 1,125,000.00
8	100.00%	Rp 0.00	Rp 250,000.00	Rp 1,000,000.00	Rp 1,250,000.00
9	100.00%	Rp 0.00	Rp 250,000.00	Rp 1,125,000.00	Rp 1,375,000.00
10	100.00%	Rp 0.00	Rp 250,000.00	Rp 1,250,000.00	Rp 1,500,000.00
11	100.00%	Rp 0.00	Rp 250,000.00	Rp 1,375,000.00	Rp 1,625,000.00

Based on the above calculations and the cost-benefit analysis, the optimization results are presented in Table 6. The table shows that the top 15 special tools studied achieved substantial cost savings. This, in essence, is thanks to the minimal initial quantities of those 15 tools. With CBA, the quantities of those special tools could be increased without incurring cost losses, while simultaneously enhancing cost savings by ensuring mechanics' needs for those tools are met without conflicts in borrowing them due to inadequate accessibility to these 15 tools. However, increasing the number of these 15 special tools does not always benefit the organization. Accordingly, CBA is employed to provide detailed cost estimates, as well as the service level, given the quantities (n) of specific special tools supplied.

Table 6. Optimization of outcome with the Cost-Benefit Analysis

Tool Number	Initial Quantity (units)	Initial Service Level Value (%)	Required (units)	Cost Savings (Rp)	Final SL (%)
190	1	69.49%	4	Rp 6,285,000	100.00%
63	2	70.76%	5	Rp 1,766,666	100.00%
48	2	67.20%	4	Rp 677,084	98.40%
33	1	66.07%	3	Rp 4,741,666	100.00%
258	2	70.45%	5	Rp 3,507,500	100.00%
222	1	68.60%	4	Rp 3,522,500	100.00%
264	2	76.54%	4	Rp 2,485,833	100.00%
11	2	72.15%	4	Rp 3,019,600	100.00%
109	1	72.15%	4	Rp 2,989,000	100.00%
95	1	75.00%	4	Rp 2,605,000	100.00%
220	1	69.01%	4	Rp 2,957,500	100.00%
191	1	75.71%	4	Rp 1,304,167	94.30%
111	1	67.65%	4	Rp 3,008,200	100.00%
32	1	75.41%	4	Rp 1,962,500	100.00%
37	2	72.88%	4	Rp 2,196,500	100.00%

Table 7. Final results of optimization

Metric	Value
Initial monthly cost for 15 special tools	Rp 48,931,414
Final monthly cost for 15 special tools	Rp 5,362,698
Total efficiency (%)	89.04%
Average initial service level value	71.27%
Average final service level value	99.51%

Optimization of the 15 special tools demonstrates a noteworthy improvement in operational performance for the enterprise. After the user follows the suggestion, the mean service level increased from 71.27% to 99.51%, while cost efficiency improved by up to 89.04% (see Table 7). These findings thus contribute to the knowledge that implementing data- and information-technology-based systems can reduce operational inefficiencies and promote sustainability. This research, in particular, strengthens a crucial finding: improving service levels does not necessarily require an excessive number of tools. Instead, a quantitative approach, including inventory optimization and CBA, is vital to ensure both cost efficiency and service sustainability. (Kirmizi et al., 2024). Consequently, integrating a digital recording system with CBA can be an effective solution for the automotive firm to manage specialized tools. In addition to improving service levels until reaching the target, this system can also mitigate the risk of delays in mechanics' tasks and provide a more rational basis for investment decision-making.

4. Conclusion

This study demonstrates that integrating a digital tool-recording system with data-driven inventory optimization significantly improves workshop operational performance. Key findings show that identifying 15 high-demand tools as bottlenecks and optimizing their stock levels through Safety Stock and CBA analysis increased service level from 86.18% to 99.51% while improving cost efficiency to 89.04%, demonstrating that even minor adjustments in lead time or service-level targets can produce notable changes in optimal stock requirements. The scientific contribution of this work lies in combining real workshop operational data, safety stock modeling, and cost–benefit simulation into a unified decision-support framework for special-tool inventory—a domain rarely explored in automotive after-sales operations. The framework provides a replicable approach that links digital traceability with quantitative optimization to reduce downtime and improve service readiness.

Despite its strong results, the study is limited by a 60-day observation window, a focus on a single workshop, and the assumption of stable demand and constant lead-time variability. Future work should explore multi-workshop datasets, machine-learning-based demand forecasting, integration of RFID/IoT for real-time tool tracking, and dynamic optimization models that account for shifting workloads and maintenance schedules. These extensions would enhance the model's robustness and support broader implementation across the automotive service network.

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