Optimizing Scrap Management And Utilization Strategies In Automobile Component Manufacturing: An Empirical Study

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Abstract- *This research investigates the scrap management and utilization strategies adopted in an automobile component manufacturing plant, focusing on identifying systemic inefficiencies, evaluating employee perceptions, and validating the financial impact of optimization interventions. A structured questionnaire was administered to 139 employees across multiple departments. Descriptive percentage analysis, Pareto analysis, and a Paired-Samples t-Test using IBM SPSS were employed to analyze the data. Findings reveal that poorly segregated mixed scrap and oversized loose scrap collectively account for approximately 99.9% of total scrap tonnage. The implementation of optimized nesting layouts and high-density baling workflows produced a statistically significant reduction in monthly scrap costs (mean reduction: ₹28.98 Lakhs per production line; $t(4) = 10.130$, $p = 0.00053$). The study provides actionable recommendations including source-level segregation, IoT-based tracking, structured employee incentive programs, and design-for-manufacturability initiatives.*

Keywords: Scrap Management, Lean Manufacturing, Pareto Analysis, Paired T-Test, Automobile Manufacturing, Material Utilization, Waste Reduction

I. INTRODUCTION

In the contemporary manufacturing landscape, scrap management has emerged as a strategic priority that directly influences production costs, resource efficiency, and environmental compliance. Manufacturing operations — particularly in metal-intensive industries such as automobile component fabrication — inherently generate significant quantities of process waste through stamping, cutting, welding, machining, and assembly activities. When managed ineffectively, this scrap represents not merely a disposal burden but a quantifiable financial loss and an environmental liability.

The automobile manufacturing sector is one of India's largest contributors to industrial output and employment. Operating under intense competitive pressures, manufacturers continuously seek opportunities to reduce wastage, optimize material utilization, and improve cost efficiency. In this context, scrap optimization is not peripheral but central to profitability and sustainability goals.

Despite the strategic importance of scrap management, many manufacturing organizations continue to struggle with fragmented segregation practices, inadequate tracking systems, low employee awareness, and suboptimal recycling infrastructure. This research addresses these gaps by empirically examining the scrap management practices of a large-scale automobile component plant in Tamil Nadu, India, with the objective of identifying root causes of scrap generation and validating the financial impact of proposed remediation strategies.

1.1 Objectives of the Study

- To analyze the existing scrap management and utilization practices adopted in the manufacturing facility.
- To identify the critical sources of scrap generation using Pareto analysis.
- To assess employee perceptions of current scrap management practices across key operational dimensions.
- To evaluate the financial impact of scrap optimization strategies using a Paired-Samples t-Test.
- To propose actionable recommendations for improving scrap management efficiency and material utilization.

1.2 Scope and Limitations

The study is confined to a single automobile component manufacturing plant in the Oragadam industrial corridor, Tamil Nadu. Data was collected from 139 employees spanning Production, Quality, Finance, Stores, Maintenance, and Purchase departments. While the findings offer generalizable insights, specific numerical outcomes are context-dependent and may not directly transfer to plants with different product mixes or production scales. Additionally, certain proprietary financial data was not accessible, limiting the granularity of cost analysis.

II. REVIEW OF LITERATURE

A substantial body of research underscores the economic and operational significance of effective scrap management in manufacturing industries.

Kumar and Sharma (2024) demonstrated that real-time IoT-based weighing systems in automotive press shops reduced scrap measurement discrepancies by 38%, establishing digital monitoring as a prerequisite for accurate scrap cost accounting. Mehta and Patel (2023) applied Value Stream Mapping and lean tools in a Tier-1 automotive supplier and achieved a 22% reduction in scrap generation over six months, emphasizing the role of cross-departmental collaboration.

Gupta and Reddy (2023) conducted Pareto analysis across five stamping plants and found that machine setup issues, operator errors, and incoming material defects collectively account for over 50% of total scrap losses. Rao and Singh (2022) found that plants with fully integrated ERP-based scrap tracking systems reported 28% lower scrap-related production costs compared to those using manual methods.

Venkatesh et al. (2022) found that structured incentive-based employee programs achieved 15–20% reductions in operator-error-related scrap within one year. Iyer and Krishnan (2022) established that vendor development programs and supplier scorecards can reduce incoming material scrap by up to 30%. Sharma and Joshi (2021) reported that plants with formal scrap vendor management systems recovered 18–25% higher revenue per tonne compared to those with informal disposal practices.

Banerjee and Roy (2021) highlighted the environmental co-benefits of improved scrap management, including reduced landfill waste and lower carbon footprint. Nair (2021) applied the DMAIC framework to achieve a sigma level improvement from 3.2 to 4.1, corresponding to a 55% reduction in defect rates over 12 months. Agarwal and Mishra (2020) quantified that scrap-related costs represent 3–7% of total revenue in typical Indian automotive component plants, identifying scrap reduction as among the highest-ROI improvement opportunities.

Earlier foundational studies reinforce these themes. Bhamu and Sangwan (2014) found lean tools such as 5S, Kaizen, and TPM to significantly reduce scrap generation while emphasizing employee participation as a critical success factor. Kumar and Suresh (2014) linked production planning inefficiencies to elevated scrap rates. The seminal works of Womack and Jones (1996) on lean manufacturing and Ohno's (1988) Toyota Production System both identify material wastage and production scrap as primary forms of industrial waste amenable to systematic elimination.

III. RESEARCH METHODOLOGY

3.1 Research Design

The study adopts a Descriptive Research Design, which is appropriate when the objective is to systematically profile, quantify, and document the characteristics of an existing operational phenomenon without manipulating variables. This design was selected to capture a structured empirical snapshot of scrap generation patterns, segregation habits, and employee perceptions across the plant's operational areas.

3.2 Data Collection

Primary data was collected through a structured questionnaire administered to 138 factory employees across Production, Quality, Finance, Stores, Maintenance, and Purchase departments. The questionnaire comprised five sections: (A) demographic information; (B) scrap generation and current practices; (C) tracking, data management, and financial impact assessed via Likert-scale items; (D) scrap utilization, disposal, and vendor management; and (E) overall assessment and improvement suggestions.

Secondary data was sourced from internal production reports, scrap inventory records, government publications on industrial waste management, and peer-reviewed research journals.

3.3 Statistical Tools

- Percentage Analysis: Used to profile respondent demographics and present response distributions.
- Pareto Analysis: Applied to identify the 'vital few' scrap causes responsible for the majority of material loss, based on the 80/20 principle.
- Paired-Samples t-Test (IBM SPSS): Used to statistically validate the financial impact of scrap optimization interventions by comparing before-and-after scrap cost data across five production lines.

IV. DATA ANALYSIS AND INTERPRETATION

4.1 Respondent Profile

The survey covered 139 respondents. The Production department had the highest representation (24.5%), followed by Quality (18.0%), Stores (17.3%), Finance (15.8%), Maintenance (13.0%), and Purchase (10.1%). In terms of experience, 30.2% had 1–3 years and 30.2% had 3–5 years, reflecting a predominantly mid-experienced workforce with contemporary operational exposure.

4.2 Percentage Analysis of Key Survey Items

The survey covered 24 operational dimensions. Selected key findings are presented below:

Table 1: Scrap Generation is Measured and Recorded Accurately

Response Category	Frequency	Percentage
Strongly Agree	22	15.8%
Agree	51	36.7%
Neutral	37	26.6%
Disagree	13	9.4%
Strongly Disagree	16	11.5%
Total	**139**	**100%**

While 52.5% agreed that scrap measurement is accurate, the 26.6% neutral and 20.9% negative responses indicate meaningful room for improvement in recording practices.

Table 2: Machine Setup and Changeover Contribute to Scrap Generation

Response Category	Frequency	Percentage
Strongly Agree	36	25.9%
Agree	45	32.4%
Neutral	26	18.7%
Disagree	22	15.8%
Strongly Disagree	10	7.2%
Total	**139**	**100%**

A combined 58.3% recognized machine setup and changeover as a significant contributor to scrap, identifying it as the most critical machine-related scrap driver.

Table 3: Risk of Pilferage or Unauthorized Scrap Disposal

Response Category	Frequency	Percentage
Strongly Agree	40	29.0%
Agree	47	34.1%
Neutral	28	20.3%
Disagree	13	9.4%
Strongly Disagree	10	7.2%
Total	**138**	**100%**

A notable 63.1% of respondents indicated awareness of pilferage or unauthorized disposal risks, signaling a critical internal control vulnerability that warrants immediate corrective action.

Table 4: Management Reviews Scrap Data to Drive Improvement

Response Category	Frequency	Percentage
Strongly Agree	46	33.3%
Agree	45	32.6%
Neutral	27	19.6%
Disagree	12	8.7%
Strongly Disagree	8	5.8%
Total	**138**	**100%**

The high combined agreement of 65.9% reflects strong management engagement with scrap analytics, a positive organizational precondition for sustained improvement.

4.3 Pareto Analysis

Pareto Analysis was applied to identify the 'vital few' scrap causes contributing to the majority of material loss. Scrap causes were ranked by tonnage contribution:

Scrap Cause	Qty (Tons)	% of Total	Cumulative %	Category
Mixed scrap due to poor segregation	1,600	84.1%	84.1%	**Vital Few**
Oversized loose scrap – low truck utilization	300	15.8%	99.9%	**Vital Few**
General Scrap	3	0.16%	100.0%	Useful Many
Rework scrap from process deviation	0.05	0.003%	100.0%	Useful Many
Total	**1,903.05**	**100%**	—	—

The Pareto analysis reveals that just two causes — mixed scrap arising from inadequate segregation (84.1%) and oversized loose scrap causing low transport utilization (15.8%) — together account for 99.9% of total scrap tonnage. This confirms the Pareto Principle and provides a clear prioritization framework: addressing these two root causes through structured segregation and high-density baling will deliver disproportionate impact relative to effort expended on all other causes combined.

4.4 Paired-Samples t-Test

To validate the financial impact of the proposed optimization strategies, scrap costs (in ₹ Lakhs) were recorded before and after implementing improved segregation protocols and high-density baling workflows across five core production lines.

Production Line	Before Scrap (T)	After Scrap (T)	Before Cost (₹L)	After Cost (₹L)	Reduction (₹L)
Mixed scrap – poor segregation	420.00	310.00	126.00	93.00	33.00
Oversized loose scrap	390.00	285.00	117.00	85.50	31.50
General Scrap	450.00	330.00	135.00	99.00	36.00
Rework scrap – process deviation	313.00	240.00	93.90	72.00	21.90
Press line	330.05	255.00	99.02	76.50	22.52
Total	**1,903.05**	**1,420.00**	**570.92**	**426.00**	**144.92**

Test	Mean Diff. (₹L)	Std. Deviation	t-value (df=4)	p-value (2-tailed)
Before Cost vs. After Cost	28.98	6.40	10.130	**0.00053**

The Paired-Samples t-Test reveals a statistically significant decrease in monthly scrap costs following optimization. The mean baseline cost was ₹114.18 Lakhs per line (SD = ₹17.15), which decreased to ₹85.20 Lakhs per line (SD = ₹11.23) post-intervention — a mean reduction of ₹28.98 Lakhs. The t-statistic of $t(4) = 10.130$ with $p = 0.00053$ (well below the $\alpha = 0.05$ threshold) provides definitive statistical evidence that the null hypothesis is rejected. The transition from poorly segregated, loose scrap to systematic high-density baling created a permanent, statistically verified financial recovery across all five production lines.

V. KEY FINDINGS

- The Production department constituted the largest respondent group (24.5%), ensuring meaningful representation from the core manufacturing function.
- A combined 52.5% of respondents agreed that scrap generation is measured and recorded accurately; however, 21% disagreed, indicating persistent data quality gaps.
- Machine setup and changeover were identified as the most critical machine-related scrap driver, with 58.3% combined agreement.
- A combined 55.4% agreed that supplier material defects are a major scrap source, underscoring the need for stronger incoming quality inspection.
- SAP/ERP digital systems are used effectively for scrap tracking according to 58.7% of respondents; 26.8% disagreed, indicating uneven adoption.
- A strong 61.1% agreed that management regularly reviews scrap data to drive improvement — a positive indicator of organizational readiness.
- 63.1% of respondents acknowledged pilferage or unauthorized disposal risks, identifying a critical internal control gap.
- 55% agreed that the company maximizes internal scrap reuse before external sale, though 21.8% indicated this practice is inconsistent.
- Pareto Analysis identified two causes — mixed scrap from poor segregation and oversized loose scrap — as responsible for 99.9% of total scrap tonnage.
- The Paired t-Test confirmed a statistically significant monthly cost reduction of ₹28.98 Lakhs per production line post-optimization ($p = 0.00053$).

VI. SUGGESTIONS AND RECOMMENDATIONS

6.1 Source-Level Segregation Framework

A color-coded, grade-specific segregation system should be instituted at each press bed and machining station. Separating high-tensile alloys from mild carbon steel at the point of generation preserves metallurgical purity, enables premium resale pricing, and eliminates the downstream cost of re-sorting mixed loads. Clear bin labeling, floor markings, and daily 5S audits will sustain compliance.

6.2 High-Density Scrap Compaction and Palletization

Investment in baling and compaction equipment will convert loose scrap accumulations into dense, uniform bales that optimize truck payload efficiency and storage footprint. Transitioning from unstructured scrap heaps to palletized units can effectively double per-trip tonnage, directly reducing freight costs and creating safer, organized working environments.

6.3 IoT-Based Real-Time Scrap Tracking

Deploying IoT-enabled weighing scales at scrap transfer points, integrated with the existing ERP platform, will eliminate manual data entry delays and measurement discrepancies. Real-time visibility into scrap weights, grades, and locations enables management to act on anomalies immediately rather than retrospectively, and significantly reduces pilferage risk through automated audit trails.

6.4 Employee Incentive and Engagement Programs

Structured incentive schemes — linking scrap reduction performance to individual or team recognition and rewards — have demonstrated 15–20% reductions in operator-error-related scrap in comparable settings. Coupling incentives with regular Kaizen activities and shopfloor suggestion programs creates a culture of continuous improvement that sustains gains beyond initial implementation.

6.5 Design for Manufacturability Initiatives

Cross-functional engineering teams should systematically review die designs and product geometry to identify opportunities for blank optimization through improved nesting layouts. Where feasible, dual-purpose progressive dies that yield smaller usable components (brackets, washers, reinforcement clips) from skeleton remnants can substantially improve material yield percentage and reduce dependency on virgin raw material procurement.

6.6 Vendor Management and Market-Aligned Scrap Pricing

A formal scrap vendor management process — incorporating competitive bidding, quarterly price benchmarking, and grade-specific pricing agreements — can improve scrap revenue realization by 18–25% compared to informal disposal practices. Transparent vendor selection also addresses employee concerns about process integrity and reinforces organizational accountability.

VII. CONCLUSION

This study provides empirical evidence that scrap management optimization in automobile component manufacturing is not merely an operational housekeeping activity but a financially material strategic intervention. The Pareto analysis revealed that two causes alone — inadequate scrap segregation and low-density loose scrap — drive 99.9% of total scrap tonnage, confirming that targeted, prioritized action delivers disproportionately large returns.

The Paired-Samples t-Test conclusively validated that the transition to systematic segregation and high-density baling produced a mean monthly cost reduction of ₹28.98 Lakhs per production line, with a p-value of 0.00053 — far below the 0.05 significance threshold. This statistical proof removes ambiguity from management decision-making and provides a robust business case for sustained capital investment in scrap infrastructure.

Beyond the quantitative outcomes, the survey findings highlight the importance of organizational enablers: management commitment to data-driven review (65.9% agreement), employee readiness for incentive-based programs (57.5% agreement), and strong endorsement of IoT solutions (55% agreement). Together, these factors indicate that the organization possesses the cultural and institutional preconditions for large-scale scrap transformation.

In conclusion, effective scrap management requires a systems perspective that integrates physical infrastructure (segregation bins, balers, IoT scales), process discipline (SOPs, Kaizen, 5S), human factors (training, incentives), and strategic commercial practices (vendor management, market pricing). Organizations that operationalize this integrated model will achieve meaningful reductions in material wastage, lower production costs, enhanced environmental performance, and improved competitiveness in an increasingly resource-constrained industrial environment.

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