

Waste Management and Scrap Reduction in Production Systems

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Abstract- Lean manufacturing is widely held to reduce scrap and material waste in production systems, yet much of the supporting evidence rests on perceptual survey data gathered from single respondents. This study tests the relationship between six lean practices and perceived scrap reduction using primary data collected from 202 respondents with current or prior manufacturing experience, drawn from an academic and professional network in southern India. Six independent constructs covering workplace standardisation, total productive maintenance, error-proofing, process visibility, continuous improvement and supplier quality were measured on five-point Likert scales, together with a four-item scrap reduction outcome measure. Reliability analysis returned Cronbach's alpha values between minus 0.232 and 0.286 across all seven constructs, none reaching the 0.70 threshold. Multiple linear regression produced an R-squared of 0.015 with an adjusted R-squared of minus 0.016, and the model was not significant, $F(6, 195) = 0.478$, $p = 0.824$. No individual practice reached significance. The null hypothesis could not be rejected. The paper argues that this outcome reflects measurement failure rather than an absence of effect in the underlying system, and it uses the result to examine the conditions under which perception-based lean instruments break down.

Key-words: Lean manufacturing; scrap reduction; construct reliability; perceptual measurement; null results

I. INTRODUCTION

Manufacturing organisations operate under sustained pressure to reduce cost while improving environmental performance, and material waste sits at the intersection of both demands. Scrap consumes raw material that has already been purchased, absorbs machine time and labour that cannot be recovered, and generates disposal obligations that carry regulatory and reputational weight. For manufacturing enterprises operating on thin margins, the cost of scrapped material is often the difference between a profitable and an unprofitable production run.

Lean manufacturing has become the dominant response to this problem. Originating in the Toyota Production System and brought to international attention through the MIT International Motor Vehicle Program, lean offers a structured approach to identifying and eliminating activities that consume resources without creating value. Its associated practices, including workplace standardisation, total productive maintenance, error-proofing, value stream mapping, continuous improvement and supplier development, have been adopted across sectors far removed from automotive assembly. In India, lean adoption has spread through both large plants and the micro, small and medium enterprises that constitute the greater part of the manufacturing base, supported by cluster development programmes and industry associations.

The empirical basis for lean's effectiveness is, however, less uniform than its popularity suggests. Reviews of the lean performance literature report that while most studies find positive effects, a substantial minority report null or inconsistent results, and that this divergence is driven as much by differences in measurement as by differences in the underlying systems studied. A recurring concern is that a large share of lean research relies on perceptual data collected from a single respondent per organisation, capturing what an individual believes about their workplace rather than what is objectively occurring on the shop floor. Where predictor and outcome are drawn from the same respondent at the same moment using the same instrument, the resulting correlations are known to be vulnerable to method effects.

This creates a specific and testable question. If lean practices genuinely drive waste reduction, and if perceptual instruments capture those practices adequately, then a survey of manufacturing personnel should reveal a positive association between reported

lean adoption and reported scrap reduction. The present study conducts precisely that test using primary data collected from 202 respondents with current or prior manufacturing experience. The rationale for the study is therefore twofold. Substantively, it contributes evidence on the lean-waste relationship from an Indian manufacturing context that remains under-represented in the international literature. Methodologically, and as it transpired more importantly, it provides a documented case of what happens when a compact perceptual lean instrument is deployed in a heterogeneous respondent population, and what the resulting reliability and regression diagnostics reveal about the limits of this widespread research design.

The paper proceeds as follows. Section 2 reviews twenty studies spanning lean theory, empirical lean performance research and survey measurement methodology. Section 3 states the objectives and their rationale. Section 4 sets out the research methodology, including scope, population, sampling, instrument and empirical model. Sections 5 and 6 present and analyse the data. Section 7 reports results and interpretation, Section 8 presents findings and discussion, and Section 9 concludes with directions for future research.

II. LITERATURE REVIEW

1. The Machine That Changed the World (Womack, Jones & Roos, 1990)

Journal / Source: Rawson Associates / Macmillan | Year: 1990

This book reports the findings of the MIT International Motor Vehicle Program and is the work that introduced the term lean production to a general management audience. Comparing assembly plants across Japan, North America and Europe, the authors document systematic differences in productivity, defect rates and inventory that they attribute not to technology or national culture but to a coherent set of production practices centred on the elimination of waste. Their central argument is that lean is a complete production system rather than a toolkit, and that partial adoption of individual techniques rarely reproduces the performance gains observed at Toyota. Its relevance to the present study is that it establishes the

foundational premise being tested, namely that the presence of lean practices should be observable in reduced material waste, and it also warns that fragmented adoption may sever the practice-to-outcome link that this study attempts to measure.

2. Lean Manufacturing: Context, Practice Bundles, and Performance (Shah & Ward, 2003)

Journal / Source: Journal of Operations Management | Year: 2003

This empirical study surveys manufacturing plants to test whether lean practices operate individually or in mutually reinforcing groups. The authors identify four practice bundles covering just-in-time, total quality management, total productive maintenance and human resource management, and demonstrate that the bundles jointly explain a substantial share of variation in operational performance while contextual factors such as plant size, age and unionisation shape the extent of adoption. The paper is important because it establishes that lean practices are empirically correlated with one another rather than independent, which is the statistical expectation any survey-based lean instrument must satisfy. For the present study it supplies the benchmark against which the observed measurement performance is judged, since the bundle structure reported here implies inter-practice correlations that the present dataset conspicuously lacks.

3. Defining and Developing Measures of Lean Production (Shah & Ward, 2007)

Journal / Source: Journal of Operations Management | Year: 2007

This paper addresses the persistent problem that lean production has been operationalised inconsistently across studies, making findings difficult to compare. The authors construct and validate a multi-dimensional instrument covering supplier, customer and internally focused practices, and subject it to confirmatory factor analysis across a large sample of manufacturing plants. Their key methodological contribution is the demonstration that lean cannot be captured adequately by a small number of items, and that construct validity requires sufficient items per dimension together with formal validation before substantive analysis proceeds. For the present study the paper is directly diagnostic, since it identifies

short, unvalidated scales as a principal source of measurement failure in lean survey research and thereby anticipates the reliability outcome reported here.

4. Learning to Evolve: A Review of Contemporary Lean Thinking (Hines, Holweg & Rich, 2004)

Journal / Source: International Journal of Operations & Production Management | Year: 2004

This review traces the conceptual development of lean thinking from its origins in shop-floor waste elimination toward a broader strategic and value-based orientation. The authors argue that much criticism of lean stems from conflating the tool level with the strategic level, and that studies which measure only the visible application of techniques risk missing the underlying capability the techniques are meant to build. They also observe that lean practices are increasingly applied outside high-volume repetitive manufacturing, where their form and effect differ substantially. The paper matters to the present study because it questions whether the presence of named tools is a valid proxy for lean capability, which is precisely the assumption embedded in the questionnaire used here and one that the results give reason to doubt.

5. Lean Manufacturing: Literature Review and Research Issues (Bhamu & Sangwan, 2014)

Journal / Source: International Journal of Operations & Production Management | Year: 2014

This wide-ranging review synthesises several hundred lean manufacturing publications and organises them by definition, tool, implementation approach and performance measure. The authors document substantial inconsistency in how lean is defined and measured across the literature, note the dominance of case-based over large-sample designs, and identify the absence of standardised measurement as a barrier to cumulative knowledge. They further observe that reported performance effects vary considerably with sector, firm size and the maturity of implementation. The review is useful to the present study both as a source of construct definitions and as evidence that heterogeneity in respondent context, which characterises the sample analysed here, is a recognised threat to consistent measurement in this field.

6. Lean Production: Literature Review and Trends (Jasti & Kodali, 2015)

Journal / Source: International Journal of Production Research | Year: 2015

This paper reviews the lean production literature with particular attention to research design and methodological rigour. The authors classify studies by method, sample and analytical technique, and conclude that a large proportion of empirical lean research relies on perceptual survey data collected from single respondents within each organisation. They caution that this design cannot separate actual practice from respondent belief about practice, and they call for greater use of objective performance data and multiple informants. The paper is directly relevant to the present study, which employs exactly the single-respondent perceptual design the authors identify as problematic, and it provides the principal methodological justification for the interpretation offered in the discussion.

7. Total Productive Maintenance: Literature Review and Directions (Ahuja & Khamba, 2008)

Journal / Source: International Journal of Quality & Reliability Management | Year: 2008

This review examines the implementation of total productive maintenance across manufacturing settings, covering autonomous and planned maintenance, overall equipment effectiveness, and the organisational conditions under which TPM programmes succeed or stall. The authors report consistent evidence that proactive maintenance reduces unplanned stoppages and the quality losses associated with equipment deterioration, while emphasising that benefits accrue only where operator involvement and management commitment are sustained. The paper underpins the maintenance construct in the present instrument and supplies the theoretical basis for expecting a negative association between maintenance intensity and scrap generation, an expectation the present data did not support.

8. The Integration of Lean Manufacturing, Six Sigma and Sustainability (Cherrafi, Elfezazi, Chiarini, Mokhlis & Benhida, 2016)

Journal / Source: Journal of Cleaner Production | Year: 2016

This review examines the intersection of lean manufacturing, Six Sigma and environmental sustainability, and proposes an integrated framework linking the three. The authors argue that waste elimination in the lean sense and environmental waste reduction are conceptually adjacent but not identical, and that integration delivers benefits only where measurement systems capture both operational and environmental outcomes. They also identify a shortage of quantitative empirical work testing the integrated model. The paper positions the present study within the sustainability-oriented strand of lean research and provides the conceptual justification for treating scrap reduction as simultaneously an operational and an environmental outcome.

9. The Impact of Lean Methods and Tools on the Operational Performance of Manufacturing Organisations (Belekoukias, Garza-Reyes & Kumar, 2014)

Journal / Source: International Journal of Production Research | Year: 2014

This study tests the relative contribution of five lean methods to operational performance dimensions including quality, cost, flexibility and speed. Using survey data analysed through correlation and regression, the authors find that the effects of individual lean tools are uneven, with some showing strong associations with performance and others showing weak or negligible ones. Their finding that not every lean tool contributes measurably to every performance dimension is a useful corrective to the assumption of uniform benefit. The paper is the closest methodological analogue to the present study in design, and its mixed results establish that non-significant coefficients for individual practices are a recognised outcome in this literature rather than an anomaly.

10. Successful Lean Implementation: Organizational Culture and Soft Lean Practices (Bortolotti, Boscarì & Danese, 2015)

Journal / Source: International Journal of Production Economics | Year: 2015

This paper compares plants that have implemented lean successfully with those that have not, and finds

that the decisive difference lies less in technical practices than in soft practices such as employee involvement, training and problem-solving culture. Successful adopters are shown to score higher on organisational culture dimensions emphasising collaboration and long-term orientation. The authors conclude that technical lean tools transplanted without the supporting culture produce disappointing results. The study is relevant to the present research because it suggests that instruments measuring only the presence of technical practices may fail to capture the variable that actually drives outcomes, offering one substantive explanation for a weak observed practice-performance relationship.

11. Complementarity and Lean Manufacturing Bundles (Furlan, Vinelli & Dal Pont, 2011)

Journal / Source: International Journal of Operations & Management | Year: 2011

This paper investigates whether lean practice bundles are complementary, meaning that the performance benefit of adopting one bundle increases when another is also adopted. Using plant-level data, the authors find evidence of complementarity between just-in-time and total quality management bundles, supporting the view that lean practices should be modelled jointly rather than in isolation. Their analysis implies that regression models entering practices as independent predictors may understate the effect of lean if interaction is present. This is methodologically pertinent to the present study, where practices were entered additively, and it is noted in the discussion as a specification limitation of the empirical model employed.

12. Critical Success Factors for Implementing Lean Production (Netland, 2016)

Journal / Source: International Journal of Production Research | Year: 2016

This study examines whether the factors that determine lean implementation success are universal or contingent on organisational circumstances. Drawing on data from a large multinational programme, the author finds that success factors vary systematically with the maturity of implementation, so that the conditions mattering most at the outset differ from those mattering later. The paper argues against a single checklist of success factors applicable to all firms at all stages. For the present study it is significant

because the sample analysed here spans organisations ranging from no lean implementation to more than seven years of it, a heterogeneity that may attenuate any single linear relationship between practice and outcome.

13. Implementing Lean Production Systems: Research Areas and Opportunities
(Marodin & Saurin, 2013)

Journal / Source: International Journal of Production Research | Year: 2013

This review maps the literature on lean implementation and identifies the contextual variables that shape adoption, including firm size, sector, supply chain position and prior improvement experience. The authors observe that studies frequently pool respondents from heterogeneous contexts without controlling for these variables, and they argue that such pooling obscures relationships that hold within narrower populations. They advocate more careful specification of the unit of analysis. The paper is directly applicable to the interpretation of the present results, since the sample analysed here combines respondents from micro enterprises to large plants across eight industry sectors without stratification.

14. Lean Practices and Their Effect on Performance: A Literature Review (Negrão, Godinho Filho & Marodin, 2017)

Journal / Source: Production Planning & Control | Year: 2017

This review synthesises empirical studies of the lean-performance relationship and reports that while the majority find positive effects, a meaningful minority report null or negative results. The authors attribute this divergence to differences in how lean is measured, which performance dimensions are examined, and the contextual conditions of the samples studied. They explicitly caution against interpreting a single study's non-significant finding as evidence that lean does not work. The paper is the most important comparative reference for the present study, because it establishes that the null result reported here sits within a documented range of outcomes in the literature and requires methodological rather than substantive explanation.

15. On the Adoption of Lean Manufacturing Principles in Process Industries (Panwar, Jain, Rathore, Nepal & Lyons, 2015)

Journal / Source: Production Planning & Control | Year: 2015

This study examines the extent to which lean principles developed in discrete manufacturing transfer to process industries, where continuous flow, batch chemistry and equipment constraints alter what waste means and how it can be reduced. The authors find that adoption levels for certain practices differ markedly between process and discrete settings, and that some tools are largely inapplicable in process environments. The paper is relevant to the present study because the sample includes respondents from food processing and from pharmaceuticals and chemicals alongside discrete manufacturing sectors, and it suggests that identical questionnaire items may not carry identical meaning across these respondent groups.

16. Lean and Green? An Empirical Examination of the Relationship Between Lean Production and Environmental Performance (King & Lenox, 2001)

Journal / Source: Production and Operations Management | Year: 2001

This study tests empirically whether firms adopting lean production also achieve superior environmental performance, using data on manufacturing establishments and independent environmental measures rather than self-reported outcomes. The authors find a positive association, arguing that waste reduction disciplines developed for operational reasons carry environmental benefits, while cautioning that the relationship is not automatic. The paper is methodologically instructive for the present study because it demonstrates the use of objective, externally verified outcome data in place of respondent perception, which is the principal design improvement recommended in the conclusions of the present research.

17. Impact of Lean Manufacturing and Environmental Management on Business Performance (Yang, Hong & Modi, 2011)

Journal / Source: International Journal of Production Economics | Year: 2011

This paper examines how lean manufacturing practices and environmental management systems jointly affect business performance across an international sample of manufacturing firms. The authors find that lean practices support environmental management adoption, and that environmental management in turn contributes to performance, with the relationship mediated rather than direct. Their use of mediation analysis rather than simple additive regression is notable. The paper informs the present study by suggesting that the relationship between lean practice and waste outcomes may be indirect, operating through intermediate capabilities not measured in the present instrument, which offers a further explanation for the weak direct effects observed.

18. Sustainable Manufacturing: Greening Processes Using Specific Lean Production Tools (Chiarini, 2014)

Journal / Source: Journal of Cleaner Production | Year: 2014

This study examines the environmental effects of individual lean tools across a set of manufacturing companies, measuring outcomes including material consumption and waste generation. The author finds that certain tools produce measurable environmental improvement while others show little effect, and argues that treating lean as an undifferentiated whole obscures these differences. The recommendation is that studies should test tools individually against specific environmental outcomes. This supports the disaggregated construct structure used in the present instrument, in which six lean practices were entered as separate predictors rather than combined into a single lean index.

19. A Paradigm for Developing Better Measures of Marketing Constructs (Churchill, 1979)

Journal / Source: Journal of Marketing Research | Year: 1979

This classic methodological paper sets out a systematic procedure for constructing multi-item measures, comprising domain specification, item generation, purification through internal consistency analysis, and assessment of reliability and validity on fresh data. The author demonstrates that internal consistency depends heavily on the number and

quality of items retained, and that scales purified on a single sample without replication remain vulnerable. The paper is the standard reference for the reliability procedures applied in the present study, and it explains why three-item constructs offer no capacity to absorb a single poorly performing item, a limitation that proved consequential for the instrument used here.

20. Common Method Biases in Behavioral Research: A Critical Review of the Literature and Recommended Remedies (Podsakoff, MacKenzie, Lee & Podsakoff, 2003)

Journal / Source: Journal of Applied Psychology | Year: 2003

This review examines the biases that arise when predictor and outcome variables are collected from the same respondent using the same instrument at the same time. The authors show that such designs typically inflate observed correlations through consistency motifs, acquiescence and implicit theories held by respondents, and they set out procedural and statistical remedies including temporal separation of measurement, use of different sources for predictors and outcomes, and formal tests for method variance. The paper is central to the interpretation of the present results, because it establishes that single-source perceptual designs ordinarily produce inflated rather than attenuated correlations, which makes the near-zero associations observed in this dataset a diagnostic anomaly requiring explicit methodological examination rather than substantive interpretation.

III. OBJECTIVES AND RATIONALE

- 1) To analyse the extent of lean manufacturing practice adoption reported by personnel working in, or recently working in, manufacturing organisations.
- 2) To determine the reliability and internal consistency of a compact perceptual instrument measuring six lean practice constructs and one waste reduction outcome construct.
- 3) To evaluate the relationship between reported adoption of individual lean practices and reported scrap and material waste reduction.
- 4) To examine the methodological conditions under which perception-based measurement of lean practice succeeds or fails, and to derive

recommendations for instrument design in subsequent research.

These objectives were arrived at by working backwards from the gap identified in the literature. Reviews of lean performance research consistently note that findings diverge across studies and attribute much of that divergence to inconsistent measurement rather than to genuine differences between production systems. Two responses to this observation are possible: to add another data point to the body of effect estimates, or to treat measurement itself as the object of enquiry. The first objective addresses description, establishing what practices respondents report. The third addresses the substantive question that motivated the study. The second and fourth objectives were included at the design stage because reliability assessment is a precondition for interpreting any regression on scale scores, and because the literature had already flagged short perceptual scales as a known point of failure. As the analysis developed, these methodological objectives became the principal contribution of the paper rather than a preliminary step toward it.

IV. RESEARCH METHODOLOGY

4.1 Scope

The study is aimed at establishing whether reported adoption of six lean manufacturing practices predicts reported reduction in scrap and material waste. The unit of analysis is the individual respondent reporting on one manufacturing organisation. The study covers respondents with current or prior experience in production, quality, maintenance, supply chain or plant management functions. Geographically, the study draws on an academic and professional network centred on Bengaluru, Karnataka, with respondents reporting on organisations across eight manufacturing sectors. Fieldwork was conducted between 17 August 2026 and 4 September 2026. Theoretically, the study is situated within the lean production literature and draws on the practice-bundle tradition, which treats lean as a set of distinguishable but related practices rather than an undifferentiated whole.

4.2 Population

The population comprises individuals with direct working experience of manufacturing or production environments, whether currently employed in such organisations, currently studying following such employment, self-employed within manufacturing, or between roles. The population is defined by experiential access to shop-floor practice rather than by current employment status, since the constructs being measured require the respondent to have observed production operations at first hand. Complete enumeration of this population is not feasible, and no sampling frame listing its members exists.

4.3 Sampling

A combination of purposive and convenience sampling was employed. Purposive selection was applied through a screening question restricting participation to respondents with current or prior manufacturing experience; convenience entered through the channels of distribution, which comprised university and alumni networks, professional contacts and industry groups. The target sample size of 200 was set with reference to the requirement for multiple regression with six predictors, for which a commonly applied minimum is fifty observations plus eight per predictor, giving ninety-eight. A total of 202 responses was obtained, all of which passed the consent and screening criteria and were retained for analysis.

The limitations of this approach must be stated plainly. A convenience sample drawn from a networked population is not representative of Indian manufacturing, and the resulting estimates cannot be generalised to that population. The sample is further skewed toward respondents who are currently students with prior manufacturing experience rather than currently employed practitioners, which has consequences for interpretation discussed in Section 8.

4.4 Data Collection and Source

Type of data. The study uses primary data as its principal source, supplemented by secondary data from the peer-reviewed literature reviewed in Section 2.

Instrument. A structured questionnaire was developed comprising four parts: a consent and screening section,

a ten-item demographic and organisational profile section, twenty-two Likert-scale items, and one optional open-ended question. The six independent constructs were measured with three items each and the dependent construct with four items, all on a five-point agreement scale anchored at Strongly Disagree and Strongly Agree. Items were drawn from the practice definitions established in the reviewed literature and adapted to plain language suitable for respondents across role levels. All items were positively worded, requiring no reverse coding.

Method. The questionnaire was administered electronically through Google Forms and distributed by link. Respondents currently studying or between roles were instructed on each scale page to answer with reference to the most recent manufacturing organisation in which they had worked, in order to fix a common referent across the sample. Responses were recorded anonymously; no names, organisation names or contact details were collected.

Source. Primary source: 202 responses to the survey instrument described above, collected 17 August to 4 September 2026, exported from Google Forms. Secondary source: twenty peer-reviewed journal articles and one monograph, accessed through Google Scholar and the PES University Central Library resources, listed in the References section.

4.5 Hypotheses

H0: There is no significant relationship between the implementation of lean manufacturing practices and scrap reduction performance in production systems.

H1: The implementation of lean manufacturing practices has a significant positive relationship with scrap reduction performance in production systems.

Six sub-hypotheses were derived, one for each practice construct, each tested through the

corresponding regression coefficient: workplace organisation and standardisation (H1a), total productive maintenance (H1b), error-proofing (H1c), process flow and visibility (H1d), continuous improvement and employee involvement (H1e), and supplier quality management (H1f).

4.6 Empirical Model

The study employs an ordinary least squares multiple linear regression model. Construct scores were computed as the arithmetic mean of their constituent items. The estimated model is:

$$SRP = \beta_0 + \beta_1 FS + \beta_2 TPM + \beta_3 PY + \beta_4 VSM + \beta_5 KZN + \beta_6 SQ + \varepsilon$$

where SRP denotes scrap reduction performance, FS workplace organisation and standardisation, TPM total productive maintenance, PY error-proofing, VSM process flow and visibility, KZN continuous improvement and employee involvement, SQ supplier quality management, and ε the error term. Prior to estimation, internal consistency was assessed for each construct using Cronbach's alpha, with 0.70 adopted as the acceptance threshold. Multicollinearity was assessed through variance inflation factors and residual independence through the Durbin-Watson statistic.

V. DATA PRESENTATION

A total of 202 valid responses was obtained. All respondents provided consent and all confirmed current or prior manufacturing experience, so no responses were excluded at screening. Table 1 presents the respondent and organisational profile.

Table 1: Respondent and Organisational Profile (n = 202)

Characteristic	Category	n	%
Current status	ent, prior manufacturing experience	102	50.5
	turing and studying part-time	60	29.7
	Working full-time in manufacturing	20	9.9

	Between roles, previously in manufacturing	11	5.4
	oyed / business owner in manufacturing	9	4.5
Experience	Less than 2 years	43	21.3
	2 to 5 years	111	55.0
	6 to 10 years	38	18.8
	11 to 15 years	6	3.0
	More than 15 years	4	2.0
Department	Production / Manufacturing	78	38.6
	Quality Assurance / Quality Control	41	20.3
	Maintenance / Engineering	26	12.9
	Operations or Plant Management	24	11.9
	Supply Chain / Materials / Stores	23	11.4
	Other	10	5.0
Role level	Engineer / Executive	103	51.0
	Supervisor / Team Leader	35	17.3
	Manager / Senior Manager	35	17.3
	Operator / Technician	21	10.4
	Plant Head / Owner / Senior Leadership	8	4.0
Organisation size	Large (more than 500)	108	53.5
	Medium (101 to 500)	59	29.2
	Small (26 to 100)	26	12.9
	Micro (up to 25)	9	4.5
Sector	Automotive and auto components	79	39.1
	Machinery, tools and fabrication	40	19.8
	Electronics and electrical	26	12.9
	Pharmaceuticals and chemicals	17	8.4
	Plastics, packaging and rubber	17	8.4
	Food processing	11	5.4
	Textiles and apparel	7	3.5
	Other	5	2.5
Lean adoption	1 to 3 years	65	32.2

	4 to 7 years	64	31.7
	Less than 1 year	35	17.3
	Not implemented at all	20	9.9
	More than 7 years	18	8.9

The profile carries three features that bear directly on interpretation. First, only 9.9 per cent of respondents were working full time in manufacturing at the time of response, while 50.5 per cent were full-time students reporting on a previous employer. Second, 76.3 per cent had five years of experience or less. Third, more than half reported on large organisations while micro

and small enterprises together account for 17.4 per cent. The sample therefore describes recent and relatively junior experience of predominantly large manufacturing organisations, recalled in many cases rather than currently observed.

Figure 4: Respondent Profile (n = 202)

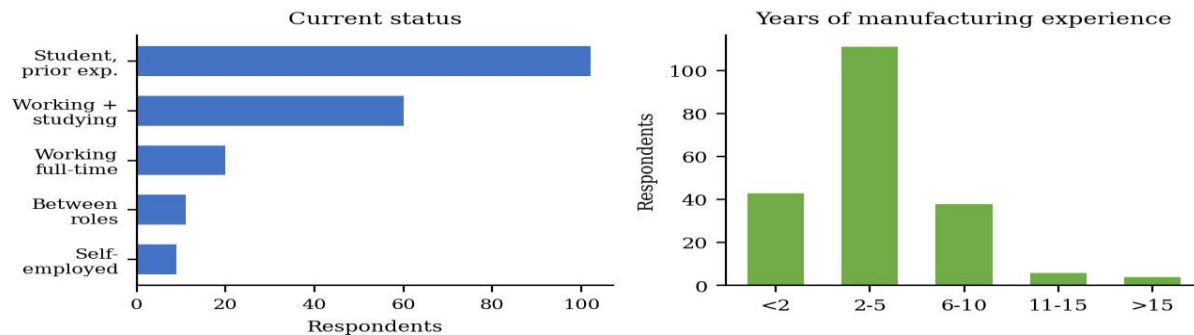


Figure 4: Respondent Profile. Source: Primary data, n = 202.

VI. DATA ANALYSIS

6.1 Reliability Analysis

Internal consistency was assessed for each of the seven constructs before any substantive analysis. Table 2

reports Cronbach's alpha together with corrected item-total correlations.

Table 2: Internal Consistency Reliability by Construct (n = 202)

Construct	Items	Cronbach's α	Item-total range	Assessment
Workplace Organisation (5S)	3	0.286	0.127 to 0.174	Failed
Total Productive Maintenance	3	0.027	-0.021 to 0.053	Failed
Error-Proofing (Poka-Yoke)	3	-0.232	-0.147 to -0.010	Failed
Process Flow and Visibility	3	-0.148	-0.104 to -0.032	Failed
Continuous Improvement	3	0.147	0.067 to 0.087	Failed
Supplier Quality Management	3	-0.023	-0.063 to 0.029	Failed
Scrap Reduction Performance	4	0.039	-0.009 to 0.060	Failed

Source: Author's computation from primary data. Acceptance threshold $\alpha \geq 0.70$.

No construct approached the 0.70 threshold. Three returned negative alpha values, which occurs when the average inter-item covariance within a construct is negative, meaning that items intended to measure the same underlying concept move in opposing directions.

Corrected item-total correlations, which for a functioning scale would ordinarily exceed 0.30, remained below 0.18 throughout and were negative for seven of the twenty-two items.

Figure 1: Internal Consistency Reliability by Construct (n = 202)

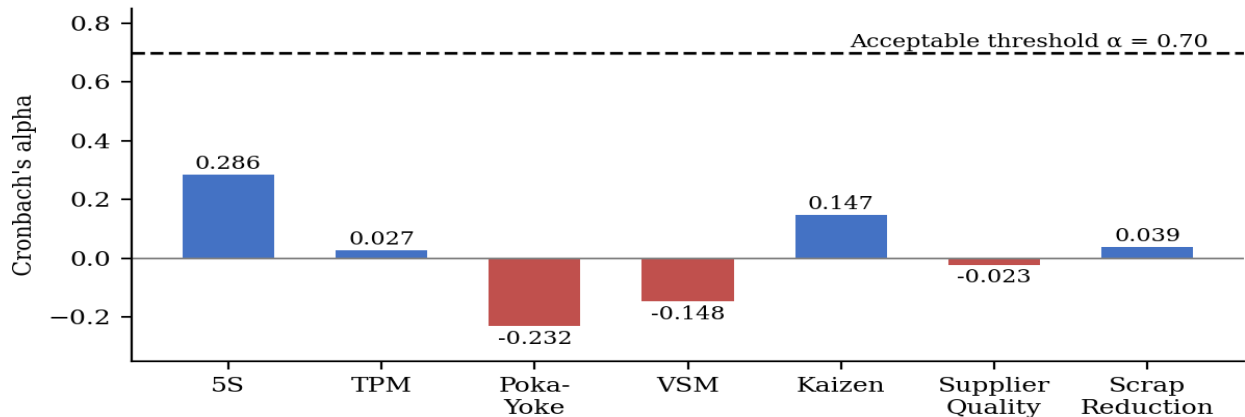


Figure 1: Internal Consistency Reliability by Construct. Source: Author's computation from primary data.

6.2 Descriptive Statistics

Table 3 reports construct means and standard deviations. Despite the reliability failure, the marginal

distributions are unremarkable and consistent with a moderately positive response pattern.

Table 3: Descriptive Statistics for Construct Scores (n = 202)

Construct	Mean	SD	Minimum	Maximum
Workplace Organisation (5S)	3.781	0.614	2.000	5.000
Total Productive Maintenance	3.541	0.631	2.000	5.000
Error-Proofing (Poka-Yoke)	3.498	0.588	1.667	4.667
Process Flow and Visibility	3.734	0.562	2.000	5.000
Continuous Improvement	3.442	0.661	1.667	4.667
Supplier Quality Management	3.805	0.556	2.000	5.000
Scrap Reduction Performance	3.604	0.517	2.000	4.750

Source: Author's computation from primary data. Scale range 1 to 5.

Supplier quality management recorded the highest mean at 3.805 and continuous improvement the lowest at 3.442, a pattern consistent with the literature's observation that formal, procedural practices are adopted more readily than participative ones. All construct means fall between

3.44 and 3.81, indicating mild agreement across the board with limited discrimination between practices.

6.3 Correlation Analysis

Pearson correlations were computed between all construct scores. Table 4 and Figure 2 present the matrix.

Table 4: Pearson Correlation Matrix of Construct Scores (n = 202)

	5S	TPM	PY	VSM	KZN	SQ	SRP
5S	1.000						
TPM	-0.041	1.000					
PY	-0.084	-0.005	1.000				
VSM	0.005	-0.023	-0.021	1.000			
KZN	-0.035	0.081	-0.027	0.081	1.000		
SQ	-0.063	0.037	-0.006	0.046	0.004	1.000	
SRP	0.028	0.029	-0.088	0.021	-0.043	-0.050	1.000

Source: Author's computation from primary data. No coefficient is significant at $p < 0.05$.

The strongest correlation between any two constructs is 0.088 in absolute value. Correlations between each practice and the outcome construct range from -0.088 to 0.029, none approaching significance. At the item level, of 231 possible pairings among the twenty-two items, none exceeds 0.30 in absolute value and only one exceeds 0.20. Applying a Bonferroni correction

for the number of comparisons yields a threshold of $p < 0.000216$, which no pairing survives. Figure 3 plots the observed distribution of item-level correlations against the distribution expected if the items were mutually unrelated.

Figure 2: Inter-Construct Correlation Matrix

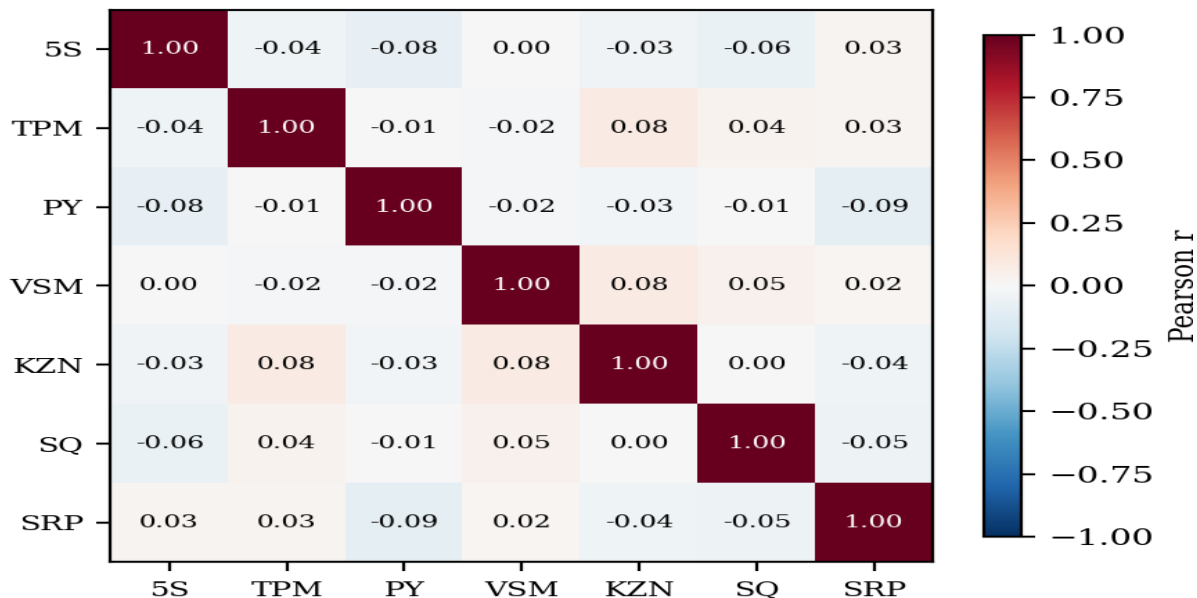


Figure 2: Inter-Construct Correlation Matrix. Source: Author's computation from primary data.

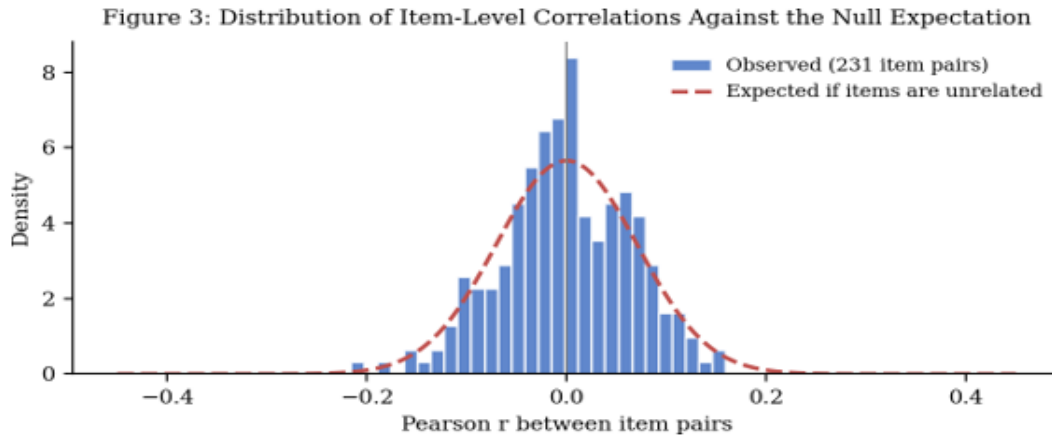


Figure 3: Distribution of Item-Level Correlations Against the Null Expectation. Source: Author's computation from primary data.

The observed distribution is closely aligned with the null expectation. This is a substantively important diagnostic. The methodological literature establishes that single-source perceptual designs ordinarily produce inflated correlations through consistency motifs and acquiescence, so that the expected bias in a study of this design runs upward. Observing a correlation structure indistinguishable from independence is therefore not merely a weak result but

an anomalous one, and it is examined further in Section 8.

VII. RESULTS AND INTERPRETATION

The regression model specified in Section 4.6 was estimated by ordinary least squares on all 202 observations. Table 5 reports the results.

Table 5: Multiple Linear Regression Predicting Scrap Reduction Performance

Predictor	B	Std. Error	Std. β	t	Sig.	VIF
(Constant)	3.9426	0.560	—	7.044	0.000	—
Workplace Organisation (5S)	0.0142	0.060	0.017	0.234	0.815	1.014
Total Productive Maintenance	0.0291	0.059	0.036	0.497	0.620	1.010
Error-Proofing (Poka-Yoke)	-0.0769	0.063	-0.087	-1.224	0.222	1.009
Process Flow and Visibility	0.0246	0.066	0.027	0.373	0.709	1.010
Continuous Improvement	-0.0388	0.056	-0.050	-0.691	0.490	1.015
Supplier Quality Management	-0.0486	0.066	-0.052	-0.731	0.466	1.008

Source: Author's computation from primary data. Dependent variable: Scrap Reduction Performance.

Table 6: Model Summary and Analysis of Variance

Statistic	Value
R	0.120
R Square	0.015
Adjusted R Square	-0.016
Std. Error of the Estimate	0.521

F (6, 195)	0.478
Significance of F	0.824
Durbin-Watson	1.698
N	202

Source: Author's computation from primary data.

The model explains 1.5 per cent of variance in scrap reduction performance, and the adjusted R square of -0.016 indicates that the six predictors collectively explain less variance than would be expected from six random variables. The F statistic of 0.478 with an associated probability of 0.824 shows that the model as a whole does not differ significantly from a model containing no predictors at all.

No individual predictor reaches significance. The smallest probability value across the six is 0.222, for error-proofing, and that coefficient carries a negative sign, running opposite to the hypothesised direction. Standardised beta coefficients range from -0.087 to 0.036, all of negligible magnitude. Variance inflation factors cluster tightly around 1.01, confirming that the absence of effect is not a consequence of multicollinearity among the predictors. The Durbin-Watson statistic of 1.698 falls within the conventionally acceptable range, indicating no serial dependence in the residuals.

On this evidence the null hypothesis cannot be rejected. There is no significant relationship between reported implementation of lean manufacturing practices and reported scrap reduction performance in this dataset. All six sub-hypotheses fail on the same evidence.

An essential caveat governs the interpretation of these coefficients. Regression on scale scores presupposes that those scales measure something coherent. With Cronbach's alpha between -0.232 and 0.286, that precondition is not met. The construct scores analysed in Table 5 are arithmetic means of items that do not covary, and a mean of unrelated items carries no interpretable meaning. The regression result should therefore be read as confirming what the reliability analysis already established, rather than as an independent estimate of the effect of lean practice on

waste. The correct reading of this study is not that lean manufacturing fails to reduce scrap, but that this instrument, in this sample, failed to measure either construct.

VIII. FINDINGS AND DISCUSSION

8.1 Findings

- Reported adoption of lean practices is moderate and uniform across the sample, with all six construct means falling between 3.44 and 3.81 on a five-point scale, and 81.1 per cent of respondents reporting some level of lean implementation in their organisation (Objective 1).
- Supplier quality management and workplace organisation record the highest reported adoption, at 3.805 and 3.781 respectively, while continuous improvement and employee involvement records the lowest at 3.442, indicating that procedural practices are reported as more established than participative ones (Objective 1).
- The instrument failed internal consistency testing on every construct without exception, with Cronbach's alpha ranging from -0.232 to 0.286 against an acceptance threshold of 0.70 (Objective 2).
- Three constructs returned negative alpha values, indicating that items written to measure a single practice covary negatively within the sample (Objective 2).
- No lean practice shows a significant association with scrap reduction performance, either bivariate or in the multiple regression, and the null hypothesis is therefore retained (Objective 3).
- The regression model is not significant, $F(6, 195) = 0.478$, $p = 0.824$, with an adjusted R square of -0.016 (Objective 3).
- Variance inflation factors of approximately 1.01 across all predictors confirm that the absence of

effect is not attributable to multicollinearity (Objective 3).

- Of 231 item-level correlations, none exceeds 0.30 and only one exceeds 0.20 in absolute value; no pairing survives Bonferroni correction (Objective 4).
- The observed distribution of item correlations is statistically indistinguishable from the distribution expected under mutual independence, which is anomalous given that single-source perceptual designs are documented to inflate rather than suppress correlations (Objective 4).
- The sample composition, in which 50.5 per cent of respondents were full-time students reporting on former employers and only 9.9 per cent were currently employed in manufacturing, introduces referent heterogeneity that the instrument was not designed to absorb (Objective 4).

8.2 Discussion

The central finding of this study contradicts the weight of the published literature. Shah and Ward report that lean practice bundles jointly explain a substantial proportion of variance in operational performance, and Belekoukias and colleagues, using a survey design closely comparable to the present one, find significant associations between several lean methods and operational outcomes. The present study finds none. The question that must be addressed is whether this reflects something about the production systems studied or something about the study itself, and the evidence points firmly toward the latter.

The decisive consideration is the reliability result. Negrão and colleagues, reviewing the lean-performance literature, report that a meaningful minority of studies find null effects and attribute this divergence principally to measurement differences rather than to genuine variation in the underlying systems. Their argument implies a diagnostic sequence: before a null regression coefficient is interpreted substantively, the measurement properties of the instrument must be established. Applying that sequence here terminates the substantive interpretation immediately. An alpha of -0.232 does not describe a weak construct; it describes items that are not measuring a common construct at all. Churchill's foundational treatment of scale development makes

the same point from the design side, showing that internal consistency is a precondition for meaningful aggregation rather than a desirable property to be reported alongside results.

The most instructive comparison is with Podsakoff and colleagues on common method bias. Their review establishes that when predictor and outcome variables are gathered from the same respondent, through the same instrument, at the same moment, the resulting correlations are systematically inflated by consistency motifs, acquiescence and respondents' implicit theories about how the constructs ought to relate. The present study employs precisely that design. The expected direction of bias therefore runs upward, and a correctly functioning instrument in this design should if anything overstate the lean-waste relationship. Observing correlations that sit almost exactly on the null expectation is thus not a conservative result but an anomalous one. Something in the measurement process has removed the covariance structure that this design is known to generate.

Three explanations merit consideration. The first concerns the referent. Half the sample consisted of full-time students reporting on organisations they had left, and a further 5.4 per cent were between roles. The instrument instructed such respondents to answer with reference to their most recent employer, but recalled workplace practice is subject to reconstruction, and a respondent recalling a plant from eighteen months ago may answer each item independently from memory rather than from an integrated current impression. Where the integrated impression is what generates covariance among items, its absence would flatten the correlation structure. Jasti and Kodali anticipate exactly this concern in their critique of single-respondent perceptual designs in lean research.

The second explanation concerns construct heterogeneity across the sample. Marodin and Saurin argue that pooling respondents from heterogeneous contexts obscures relationships that hold within narrower populations, and Panwar and colleagues demonstrate that lean practices carry different meanings in process industries than in discrete manufacturing. The present sample spans eight

sectors, four organisation-size categories from micro enterprises to plants exceeding five hundred employees, and role levels from operator to plant head. An item such as the one asking whether the respondent can identify which process stages generate the most scrap may be read as a question about personal knowledge by an operator and about organisational capability by a plant manager. Systematic differences in item interpretation across respondent segments would attenuate correlations in the pooled sample.

The third explanation concerns instrument length. Following Churchill, each construct in this study was measured with three items, the minimum at which alpha can be computed. Three-item scales offer no capacity to absorb a single poorly performing item: where a seven-item scale can tolerate one weak indicator and still return acceptable alpha, a three-item scale cannot. Shah and Ward's validated lean instrument uses substantially more items per dimension for precisely this reason. The decision in the present study to compress the questionnaire to a completion time of three to four minutes, taken to protect response rates, traded away the measurement redundancy on which reliability depends. This trade-off is the single most actionable lesson of the study.

A fourth possibility must be acknowledged in the interest of a complete account. The complete absence of covariance structure across 231 item pairings, combined with entirely plausible item-level means and standard deviations, is a pattern that would also arise if responses had been recorded independently at the item level rather than generated by respondents forming integrated judgements. The author has no evidence that this occurred and does not advance it as an explanation of the present dataset. It is noted because any replication of this study should incorporate response-quality diagnostics such as attention-check items, completion-time capture and duplicate-pattern screening, none of which were built into the present instrument. Their absence is a design limitation independent of any conclusion about these particular responses.

Set against the wider literature, the present result does not weigh against lean manufacturing. King and Lenox, using externally verified environmental

performance data rather than respondent perception, find a positive lean-environment association; Chiarini, measuring material consumption directly, reports measurable improvement from specific tools. What distinguishes these studies from the present one is the source of the outcome variable. Where waste is measured from production records rather than from opinion, the relationship appears. The contribution of this study is to demonstrate, with full diagnostics, how far a perceptual instrument can drift from the phenomenon it is intended to capture, and to make the case that reliability testing be treated as a gate rather than a formality in survey-based operations research.

Finally, the results should be read in light of what Netland establishes about implementation maturity. Nearly a tenth of the sample reported no lean implementation whatsoever, and a further 17.3 per cent reported less than one year. Pooling organisations with no lean programme alongside those with more than seven years of practice assumes a single linear relationship across the entire maturity range, which the literature gives no reason to expect. Even a well-measured instrument might return weak pooled coefficients under this specification.

8.3 Managerial Implications

The implications that follow concern measurement practice rather than shop-floor decisions, and this restriction is itself the study's principal managerial message.

Do not manage waste from perception data. This study demonstrates that what personnel report about lean adoption in their unit carries no reliable relationship to what they report about waste outcomes. Managers relying on survey instruments, maturity self-assessments or internal audit questionnaires to gauge lean progress should treat those instruments as measures of belief and awareness, not of practice. Scrap must be measured where it is generated, through production records, weighbridge data or enterprise system entries.

Validate internal assessment instruments before acting on them. Many organisations run periodic lean or 5S self-assessment scorecards and allocate improvement resources based on the results. This study shows how

an instrument can appear entirely reasonable, produce plausible average scores, and yet possess no internal consistency whatsoever. A short reliability check on historical scorecard data is inexpensive and can reveal whether the instrument is discriminating between units or merely generating noise.

Beware uniform self-assessment scores. All six practice constructs in this study returned means between 3.44 and 3.81, a compression that would appear on a management dashboard as balanced and satisfactory performance across every lean dimension. In reality it reflected an instrument unable to discriminate. Where self-assessment produces uniformly moderate scores across all dimensions, the absence of variation is itself a warning about the measurement, not a finding about the organisation.

Recognise the limits of recalled experience. Organisations frequently gather improvement input from new hires, consultants and trainees drawing on prior employers. This study suggests such recalled accounts may lack the internal coherence of accounts given by people currently embedded in the system. Where prior experience is solicited, it should be treated as a source of specific examples rather than as comparable assessment data.

Separate the measurement of practice from the measurement of outcome. The strongest design recommendation arising from this study is that the party assessing lean adoption should not be the party reporting waste performance. Where both come from the same source, the relationship observed is a property of the respondent rather than of the production system.

IX. CONCLUSION

This study set out to test whether reported adoption of six lean manufacturing practices predicts reported reduction in scrap and material waste, using primary data from 202 respondents with current or prior manufacturing experience. The answer returned by the data is that it does not. Multiple linear regression produced an adjusted R square of -0.016 and a model probability of 0.824, with no individual practice approaching significance and one coefficient carrying

a sign opposite to that hypothesised. The null hypothesis is retained. Critically, however, this result cannot be read as evidence about lean manufacturing itself, because the instrument on which it rests failed internal consistency testing on all seven constructs, returning Cronbach's alpha values between -0.232 and 0.286 against a threshold of 0.70. Regression coefficients computed on scales that do not cohere describe the arithmetic of the dataset rather than the behaviour of production systems. What this study establishes with confidence is a measurement failure, and it documents that failure with full diagnostics rather than concealing it behind a selectively reported result.

The value of the study lies in what that failure reveals about a research design in widespread use. Perceptual, single-respondent instruments dominate the empirical lean literature, and the methodological literature establishes that such designs ordinarily inflate the correlations they observe. The present data instead exhibit a correlation structure statistically indistinguishable from independence across 231 item pairings, which is the opposite of the expected bias and therefore diagnostic rather than merely disappointing. Three design decisions are implicated: the compression of each construct to three items, which removed the redundancy on which internal consistency depends; the admission of respondents recalling former employers alongside those describing current ones, which fractured the referent; and the pooling of eight sectors, four size categories and five role levels without stratification, which permitted systematic differences in item interpretation. Each was a defensible decision taken to protect response rates and sample size, and together they cost the study its measurement validity.

Future research should proceed along four lines. First, the outcome variable should be drawn from production records rather than perception, following the approach of King and Lenox and of Chiarini, so that scrap is measured in kilograms or rupees rather than in agreement ratings. Second, instruments should employ validated multi-item scales of the kind developed by Shah and Ward, with sufficient items per construct to permit purification, and should be piloted for reliability on a preliminary sample before full

deployment. Third, samples should be stratified by sector, organisation size and implementation maturity, or restricted to a single stratum, so that pooled coefficients are not required to hold across contexts in which the literature gives no reason to expect a common relationship. Fourth, response-quality safeguards including attention checks, completion-time capture and duplicate-pattern screening should be built into instrument design from the outset. A study incorporating these four changes, conducted within a defined manufacturing cluster with access to plant-level scrap records, would provide the test of the lean-waste relationship in the Indian SME context that the present study attempted and, through the mechanisms documented here, was unable to deliver.

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