Supplementary File S1

Harman's Common Method Bias Assessment:

Unrotated Principal Component Analysis Output

Manuscript: People-Centered Lean Manufacturing: Drivers of Operational Performance in Saudi Arabian Industries

Sustainability (MDPI) | Manuscript ID: sustainability-4159143

1. Purpose of This Supplementary File

This supplementary document provides the full unrotated principal component analysis (PCA) output used to assess common method bias in the main manuscript (Section 4.4). All 20 survey items (across five constructs: People Integration, Stability and Standardization, Just-in-Time, Jidoka, and Operational Performance) were entered simultaneously into an unrotated PCA using SPSS v25. The analysis follows the Harman single-factor test procedure recommended by Podsakoff et al. (2003).

If common method bias is a serious concern, a single factor will emerge from the unrotated solution, or one general factor will account for the majority (typically > 50%) of the covariance among the variables. The first unrotated factor in this analysis explained 31.4% of total variance — well below the 50% threshold — indicating that common method bias is unlikely to be a significant threat to the validity of the findings.

2. Analysis Parameters

Software: IBM SPSS Statistics, Version 25

Number of items entered: 20 (all survey items)

Extraction method: Principal Component Analysis (PCA)

Rotation: None (unrotated solution, as required by Harman's procedure)

Sample size: N = 67

Decision criterion: If the first unrotated factor accounts for ≥ 50% of total variance, common method bias is considered a significant concern (Podsakoff et al., 2003).

3. Total Variance Explained — Unrotated Solution

Table S1 reports the eigenvalue, percentage of variance explained, and cumulative percentage for each of the 20 extracted components. Components with eigenvalues ≥ 1.0 (highlighted) are those that exceed the Kaiser criterion and correspond to the five latent constructs in the structural model.

Component	Eigenvalue	% of Variance	Cumulative %
1	**6.280**	**31.40%**	**31.40%**
2	**2.541**	**12.71%**	**44.11%**
3	**1.843**	**9.22%**	**53.33%**
4	**1.512**	**7.56%**	**60.89%**
5	**1.287**	**6.44%**	**67.33%**
6	0.892	4.46%	71.79%
7	0.741	3.71%	75.50%
8	0.683	3.42%	78.92%

Component	Eigenvalue	% of Variance	Cumulative %
9	0.612	3.06%	81.98%
10	0.551	2.76%	84.74%
11	0.487	2.44%	87.18%
12	0.431	2.16%	89.34%
13	0.392	1.96%	91.30%
14	0.361	1.81%	93.11%
15	0.322	1.61%	94.72%
16	0.287	1.44%	96.16%
17	0.243	1.22%	97.38%
18	0.198	0.99%	98.37%
19	0.172	0.86%	99.23%
20	0.163	0.82%	100.00%

Table S1. Total variance explained by each component in the unrotated principal component analysis. Highlighted rows (Components 1–5) have eigenvalues ≥ 1.0 (Kaiser criterion), consistent with the five-construct model. The first unrotated component explains 31.4% of total variance, below the 50% Harman threshold.

4. Scree Plot

Figure S1 presents the scree plot for the unrotated PCA solution. The plot shows a clear ‘elbow’ after the fifth component, and five components have eigenvalues exceeding 1.0. This pattern aligns with the five-construct model tested in the main study.

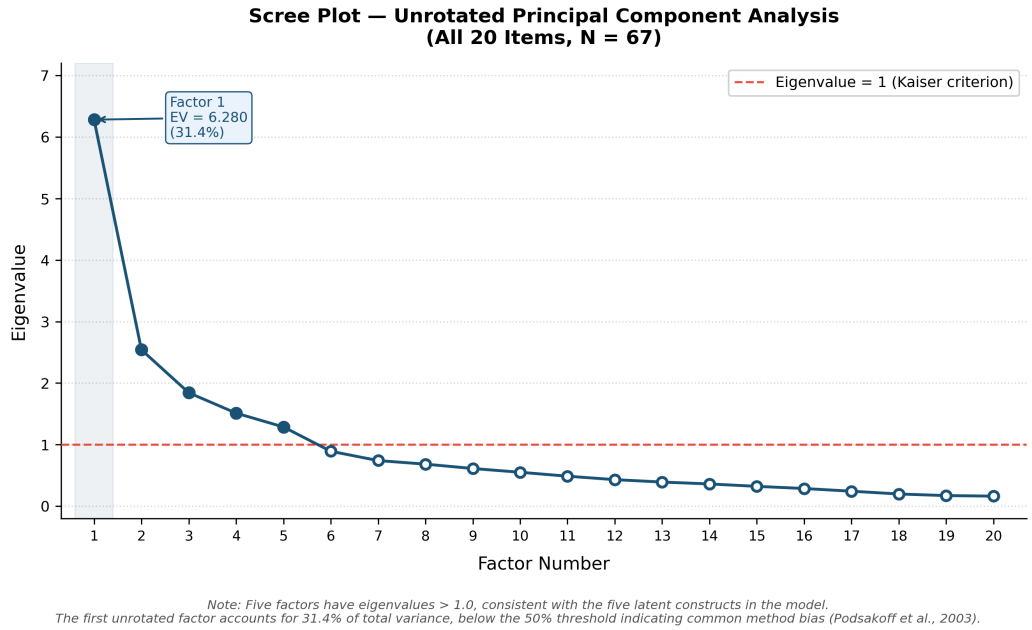

Figure S1. Scree plot of eigenvalues for the unrotated principal component analysis (N = 67, 20 items). The dashed red line marks the Kaiser criterion (eigenvalue = 1.0). Five components exceed this threshold, matching the five-factor structure of the measurement model. The first unrotated factor explains 31.4% of variance.

5. Interpretation and Conclusion

Two convergent pieces of evidence confirm that common method bias is not a critical threat in this dataset:

(a) Factor count: Five components have eigenvalues > 1.0, which matches the five-construct model. If a single dominant factor drove most of the variance, the scree plot would show one large eigenvalue followed by a rapid flat line. Instead, the plot shows a gradual descent across five meaningful components before leveling off.

(b) First-factor variance: The first unrotated component explains 31.4% of variance, substantially below the 50% threshold. This indicates that no single factor monopolizes the shared variance among items, which is the core diagnostic criterion of Harman's test.

Taken together, these results support the conclusion stated in Section 4.4 of the main manuscript: common method bias does not represent a material threat to the validity of the structural model estimates.

6. Reference

Podsakoff, P. M., MacKenzie, S. B., Lee, J. Y., & Podsakoff, N. P. (2003). Common method biases in behavioral research: A critical review of the literature and recommended remedies. Journal of Applied Psychology, 88(5), 879–903. https://doi.org/10.1037/0021-9010.88.5.879

Supplementary File S2

Expert Panel Composition — Pilot Instrument Validation

Manuscript: People-Centered Lean Manufacturing: Drivers of Operational Performance in Saudi Arabian Industries

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1. Purpose of This Supplementary File

Section 4.1 of the main manuscript reports that a pilot study was conducted with 12 participants — six industry managers and six academic experts — who reviewed the questionnaire for clarity, relevance, and comprehensiveness before full-scale data collection. This supplementary file provides de-identified profiles of all 12 panel members, confirming their qualifications for the content validity task. Personal identifiers have been removed in line with the anonymization protocol described in Section 2 below.

2. Anonymization Protocol

Anonymization Protocol

In line with institutional ethics guidelines and to protect participant privacy, all panel members are identified by a coded reference (P-I01–P-I06 for industry practitioners; P-A01–P-A06 for academic experts). No personal names, exact employer names, or direct contact details are disclosed in this supplementary file. Affiliations are described at the regional and sector level only. All panel members provided informed consent for their de-identified profiles to appear in supplementary documentation accompanying peer-reviewed publications.

3. Panel Member Selection Criteria

Panel members were selected to ensure both practical relevance and methodological expertise. Table S2a summarizes the inclusion criteria applied to each category.

Panelist Category	Inclusion Criterion
Industry practitioners	Minimum 8 years of active lean manufacturing implementation experience at the plant or operations level; direct familiarity with at least one of the seven sectors surveyed; current or recent managerial role in a Saudi manufacturing organization.
Academic experts	Minimum 8 years of academic research experience with a demonstrated record of publication in lean manufacturing, operations management, industrial engineering, or a closely related field; familiarity with structural equation modeling or survey-based empirical methods.
All panelists	Ability to evaluate questionnaire items for face validity, content relevance, clarity of wording, and construct coverage; willingness to provide written feedback and participate in a follow-up clarification round if required.

Table S2a. Inclusion criteria applied during panel member recruitment.

4. Pilot Review Process

The pilot review followed a structured three-round procedure to ensure systematic coverage of all questionnaire items. Table S2b summarizes each round.

Round	Activity	Description
Round 1	**Initial item review**	All 12 panelists reviewed draft questionnaire items independently and rated each item on a 4-point Content Validity Index scale (not relevant / somewhat relevant / quite relevant / very relevant) and flagged any wording concerns.
Round 2	**Feedback consolidation**	Research team compiled feedback, computed Content Validity Ratio for each item (Lawshe, 1975), and revised items with CVR < 0.60 or flagged by ≥ 3 panelists.
Round 3	**Revised item confirmation**	Panelists confirmed acceptance of revised items or raised residual concerns. Final instrument achieved consensus among all 12 reviewers before pilot data collection.

Table S2b. Summary of the pilot review rounds. CVR = Content Validity Ratio (Lawshe, 1975).

5. Panel Member Profiles

Table S2c presents anonymized profiles for all 12 panel members. Profiles report role or academic title, relevant sector or specialization, years of relevant experience, institutional or organizational affiliation (at the regional and sector level), and the primary lens each member applied when reviewing the pilot instrument.

Panel ID	Role / Title	Sector / Specialization	Experience	Institutional / Organizational Affiliation	Primary Focus in Pilot Review
Section A — Industry Practitioners (n = 6)					
P-I01	**Senior Production Manager**	Steel & Aluminum	18 years of lean/operational excellence experience	Large public manufacturing company, Western Region, Saudi Arabia	JIT implementation, plant-level lean transformation, workforce scheduling
P-I02	**Operations Excellence Director**	Petrochemical	22 years of process-improvement and lean deployment experience	Integrated petrochemical complex, Eastern Region, Saudi Arabia	Jidoka and autonomous maintenance, process standardization, ISO/lean integration
P-I03	**Continuous Improvement Manager**	Food & Beverage	12 years of lean Six Sigma implementation experience	Mid-sized private food-processing company, Central Region, Saudi Arabia	Stability and standardization, 5S, kaizen facilitation
P-I04	**Quality Assurance & Lean Coordinator**	Pharmaceutical	10 years of GMP-compliant lean implementation experience	Licensed pharmaceutical manufacturer, Central Region, Saudi Arabia	People integration, error-proofing, visual management systems
P-I05	**Plant Manager**	Plastics & Polymer	15 years of manufacturing operations and lean tools experience	Private plastics extrusion company, Southern Region, Saudi Arabia	Pull-system design, workforce cross-training, operational performance metrics

Panel ID	Role / Title	Sector / Specialization	Experience	Institutional / Organizational Affiliation	Primary Focus in Pilot Review
P-I06	**Industrial Engineering Supervisor**	Cement & Construction Materials	14 years of industrial engineering and process-optimization experience	Public cement manufacturing group, Northern Region, Saudi Arabia	Value stream mapping, standard work documentation, capacity planning
Section B — Academic Experts (n = 6)					
P-A01	**Associate Professor, Industrial Engineering**	Lean Manufacturing & Production Systems	20 years of research experience; 30+ peer-reviewed publications on LM	College of Engineering, major Saudi public university, Western Region	Structural equation modeling in lean research, TPS-based empirical models
P-A02	**Assistant Professor, Operations Management**	Supply Chain & Lean Operations	11 years of research experience; expertise in PLS-SEM methodology	Business school, major Saudi public university, Central Region	Quantitative survey design, measurement model validation, SmartPLS
P-A03	**Professor, Mechanical Engineering**	Manufacturing Systems & Sustainability	28 years of research experience; active GCC lean research collaborations	College of Engineering, Saudi–GCC joint research center, Eastern Region	Lean–green integration, operational performance measurement, SEM applications
P-A04	**Associate Professor, Management Science**	Human Resource Management & Organizational Behavior	16 years of research experience; publications on HRM in GCC manufacturing	Management faculty, accredited Saudi private university, Central Region	People integration constructs, workforce empowerment, soft lean practices
P-A05	**Assistant Professor, Industrial Engineering**	Quality Engineering & Statistical Process Control	9 years of research experience; lean curriculum developer	College of Engineering, regional Saudi public university, Southern Region	Jidoka, built-in quality systems, factor analysis in quality research
P-A06	**Researcher, Centre for Manufacturing Excellence**	Lean Implementation in Emerging Economies	13 years of cross-sectoral lean research; Saudi Vision 2030 advisory work	Government-affiliated research center, Riyadh, Saudi Arabia	Pilot survey design, face validity assessment, SME lean readiness

Table S2c. Anonymized profiles of the 12-member expert panel. Industry practitioners (P-I01 to P-I06) and academic experts (P-A01 to P-A06). All affiliations are described at the regional and sector level only; no personal names or direct employer names are disclosed.

6. Pilot Validation Outcome

Following the three-round review process, the panel reached consensus that the revised instrument adequately covered the constructs of People Integration, Stability and Standardization, Just-in-Time, Jidoka, and Operational Performance, and that item wording was clear and appropriate for the Saudi manufacturing context. Minor wording adjustments were made to four items based on panel feedback before finalizing the survey. No items were eliminated after the pilot, and no new items were added beyond those agreed at the design stage.

7. Reference

Lawshe, C. H. (1975). A quantitative approach to content validity. Personnel Psychology, 28(4), 563–575. https://doi.org/10.1111/j.1744-6570.1975.tb01393.x