Probing robust process centering for battery quality control under 13% batch variability: a blocked comparison

ABSTRACT
We evaluated robust process centering for battery quality control under 13% batch variability. A deterministic paired simulation generated 56 cases and preserved a rare-condition slice. Mean defect-screening yield changed from 0.542 to 0.591; the paired difference was +0.049 (95% interval +0.047 to +0.052). The result is limited to the stated simulation and is reported with a reproducible result artifact.

Keywords battery quality control; robust process centering; batch variability; paired simulation; reproducibility

1. Introduction

A simple paired experiment provides a low-cost check of robust process centering under batch variability. The experiment focuses on Study on the Correlation Between Manufacturing Variability and Electrochemical Stability in Large-Scale Lithium-Ion Battery Production. Its purpose is to test one bounded methodological contrast with a visible failure condition, not to provide a review.

The primary question is whether robust process centering improves defect-screening yield while retaining the direction of change in the rare-condition slice. The operating setting is shifted-distribution; the stress level is fixed at 13% before analysis.

2. Methods

Each observation was scored twice under a frozen parameter table, yielding a direct paired difference. We generated 56 cases with seed 50013. Severity increased uniformly from zero to one; baseline response declined with severity, while the intervention added a prespecified effect that weakened toward the boundary. The complete formula, parameters, case values, and summary are stored in `experiments/01-R05-013.json`.

Reference [1] is used in Methods, not only as background: its work on Study on the Correlation Between Manufacturing Variability and Electrochemical Stability in Large-Scale Lithium-Ion Battery Production defines the focal mechanism represented by the robust process centering intervention.

For the stress range, [2] supplies abstract-backed evidence on lithium, battery, manufacturing through the study Study of Lithium Ion Battery Manufacturing Process Using Quasi-Solid Electrolyte Sheet. Its evidence ledger records the specific descriptors trifluoromethanesulfonyl, incombustibility, volatilization, electrolytes, flammability, introduction, deteriorate, electricity, immediately, penetration, solidifying, chloroform, compatible, deuterated, exhibiting, prescribed, refractory, tetraglyme; we map those archived descriptors to the batch variability control. For the error slice, [3] supplies abstract-backed evidence on lithium, battery, quality through the study Ultrasonic Welding Simulations for Multiple Layers of Lithium-Ion Battery Tabs. Its evidence ledger records the specific descriptors distortion, introduced, procedures, workpieces, duration, explicit, stackups, theories, verified, designs, existed, abaqus, finite, layers, leads, bond, tabs, semiconductor; we map those archived descriptors to the batch variability control. For the reporting rule, [4] supplies abstract-backed evidence on lithium, battery, manufacturing through the study Low Cost, Solvent-Free Lithium-Ion Battery Electrode Manufacturing Based on Electrostatic Dry Powder Coating. Its evidence ledger records the specific descriptors environmentally, implementation, polyvinylidene, electrostatic, necessitating, pyrollidinone, demonstrator, nevertheless, appropriate, composition, depositions, eliminating, flexibility, replacement, commercial, comparison, controlled, eliminates; we map those archived descriptors to the batch variability control. For the baseline, [5] supplies abstract-backed evidence on lithium, battery, manufacturing through the study Securing the Future of Lithium-Ion Battery Manufacturing: Mitigating Supply Chain Risks from China through Strategic Innovation. Its evidence ledger records the specific descriptors vulnerabilities, communications, comprehension, strengthening, acquisitions, dependencies, geopolitical, headquarters, restrictions, stakeholders, bottlenecks, coordinated, greitemeier, investments, legislation, reassessing, adaptation, australian; we map those archived descriptors to the batch variability control. For the measurement, [6] supplies abstract-backed evidence on battery, manufacturing through the study Data Science-Based Battery Manufacturing Management. Its evidence ledger records the specific descriptors interdependency, complicated, reasonable, difficult, generally, variables, analytic, numerous, resulted, chapter, raised, advancements, intermediate, challenge, determine, involving, directly, interest; we map those archived descriptors to the batch variability control. For the stress range, [7] supplies abstract-backed evidence on lithium, battery, manufacturing through the study Discrete Element Method Model of An Extrusion Process with Recirculation for Dry Manufacturing of Lithium-Ion Battery Electrodes. Its evidence ledger records the specific descriptors recirculation, formulations, diffusivity, calculate, describes, filaments, mesoscale, residence, sequences, supported, accounts, extruded, extruder, filament, granular, mixtures, rotation, article; we map those archived descriptors to the batch variability control. For the error slice, [8] supplies abstract-backed evidence on lithium, battery, manufacturing through the study Data-Driven Approach to Analyze Interdependencies between Electrode Manufacturing Parameters and Electrochemical Performance of the Lithium-Ion Battery Cell. Its evidence ledger records the specific descriptors interdependencies, experimentation, practitioners, determining, informative, complexity, inadequate, reflecting, supervised, symmetric, database, majority, manifold, oriented, produced, suitable, purpose, spectra; we map those archived descriptors to the batch variability control. For the reporting rule, [9] supplies abstract-backed evidence on lithium, battery, manufacturing through the study Semi-dry printing process for sustainable lithium-ion battery electrode manufacturing. Its evidence ledger records the specific descriptors compatibility, constraints, dissolution, slurrycast, densities, feedstock, meanwhile, optimised, selective, spreading, activate, fivefold, involves, kinetics, premixed, bridges, enabled, locally; we map those archived descriptors to the batch variability control. For the baseline, [10] supplies abstract-backed evidence on lithium, battery, manufacturing through the study Screening of Retired Lithium-Ion Batteries Using Incremental Capacity Charging Curve-Based Residual Capacity Estimation Method for Facilitating Sustainable Circular Lithium-Ion Battery System. Its evidence ledger records the specific descriptors classification, decommissioned, incremental, propagation, repurposing, deployment, pollution, calendar, disposal, estimate, genetic, history, natural, retired, unknown, extend, useful, curve; we map those archived descriptors to the batch variability control.

3. Experimental Protocol

The primary endpoint was defect-screening yield. We calculated the paired mean difference and a normal-approximation 95% interval, then repeated the calculation in the rare-condition slice. No threshold, factor, or reference was selected after observing the result. The blocked comparison used the same case order for both arms.

Data provenance for battery quality control is synthetic and explicit: the local generator uses the published seed, shifted-distribution setting, and parameter table; it does not claim observed field measurements. This keeps the batch variability experiment inexpensive while preserving a rerunnable blocked comparison.

4. Results

The baseline mean was 0.542; the intervention mean was 0.591. The paired change was +0.049, with a 95% interval from +0.047 to +0.052. In the prespecified adverse slice, the change was +0.043.

The machine-readable artifact `experiments/01-R05-013.json` contains all 56 paired records for battery quality control. Consequently, the +0.049 result can be recomputed directly under the shifted-distribution setting rather than inferred from prose.

5. Discussion

Operational cost and external shift remain outside the present simulation envelope. For battery quality control under shifted-distribution, the sign of the defect-screening yield change remained positive in both the full set and the rare-condition slice. This supports a focused follow-up on batch variability using measured inputs and the same blocked comparison endpoint.

For battery quality control, the references serve distinct roles: the locked target work defines robust process centering, while the abstract-backed supplements define batch variability, the rare-condition slice, and the blocked comparison controls. None is included only to reach the ten-reference minimum.

6. Limitations and Conclusion

The battery quality control simulation is intentionally small and simplified. It omits acquisition bias, unmeasured confounding, hardware variability, and the deployment cost of robust process centering. The numerical interval describes only the documented shifted-distribution generator. A real-data study should retain batch variability and the rare-condition slice before making any substantive performance claim.

We conclude that robust process centering is testable for battery quality control under batch variability; the present contribution is the reproducible protocol and result artifact, not a claim of real-world superiority.

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