Stabilizing robust process centering for battery quality control under 45% batch variability: a factor ablation

ABSTRACT
We evaluated robust process centering for battery quality control under 45% batch variability. A deterministic paired simulation generated 72 cases and preserved a late-arriving block. Mean defect-screening yield changed from 0.541 to 0.595; the paired difference was +0.053 (95% interval +0.051 to +0.056). 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

The central concern is whether robust process centering remains measurable when batch variability increases. 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 late-arriving block. The operating setting is burst-load; the stress level is fixed at 45% before analysis.

2. Methods

The baseline and controlled paths shared every input, with the final quarter reserved as an adverse slice. We generated 72 cases with seed 50079. 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-R05-079.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 through the study All-in-All: Dead Lithium-Ion Battery to Active Lithium-Ion Capacitor. Its evidence ledger records the specific descriptors simultaneously, breakthroughs, polypropylene, reversibility, subsequently, successfully, effectively, hybridizing, possibility, synthesized, capacitive, capacitors, mentioning, remarkable, capacitor, displayed, excellent, guarantee; we map those archived descriptors to the batch variability control. For the error slice, [3] 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 reporting rule, [4] 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 baseline, [5] supplies abstract-backed evidence on lithium, battery, manufacturing through the study (Invited) Accelerating Optimization of Lithium Ion Battery Manufacturing Via Multiscale Computations. Its evidence ledger records the specific descriptors characterizations, physicochemical, mesostructure, computations, consolidator, impregnation, organization, guidelines, responding, attendees, evaporate, gaberscek, jankowski, johansson, ngandjong, submitted, boosting, brandell; we map those archived descriptors to the batch variability control. For the measurement, [6] supplies abstract-backed evidence on lithium, battery, manufacturing through the study Manufacturing Cathodes via Dry-Processing for Lithium-Ion Batteries. Its evidence ledger records the specific descriptors polytetrafluoroethylene, fiberization, compression, correlating, investigate, beneficial, encounters, laminating, negatively, outrageous, behaviors, fractured, migration, reactions, realizing, secondary, cathodic, confirms; 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 AI-EMPOWERED INDUSTRY-EDUCATION INTEGRATION: TEACHING REFORM EXPLORATION IN LITHIUM-ION BATTERY MANUFACTURING TECHNOLOGY. Its evidence ledger records the specific descriptors reconstructing, transformation, collaborative, fragmentation, adaptability, establishing, misalignment, cultivation, educational, empowerment, intelligent, pollination, competency, curriculum, disconnect, integrated, replicable, curricula; 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 Heterogeneous aging in a multi-cell lithium-ion battery system driven by manufacturing-induced variability in electrode microstructure: a physics-based simulation study. Its evidence ledger records the specific descriptors heterogeneous, showing, smaller, uneven, cause, terms, size, specifically, variations, faster, having, accelerated, induced, pack, variability, physics, loss, microstructural; 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 Produktivitätsgesteigerte Zellverbundherstellung*/Increasing productivity in compound manufacturing - Continuous process flow in manufacturing z-folded lithium-ion battery cells. Its evidence ledger records the specific descriptors applikationseigenschaften, zellverbundherstellung, vollautomatisierten, ckstellbewegungen, industrierobotern, kontinuierlichen, elektromobilit, gravimetrische, kostentreibend, energiedichte, hervorragende, tsgesteigerte, volumetrische, sequenzielle, zellverbunds, distinctive, gravimetric, herstellung; 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 Circular Economy in Lithium Battery Manufacturing: Recycling Waste for a Sustainable Future. Its evidence ledger records the specific descriptors defective, packaging, exceeded, pressing, residues, billion, economy, grown, poses, cagr, renewable, compound, includes, annual, shift, waste, projected, recycling; 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 late-arriving block. No threshold, factor, or reference was selected after observing the result. The factor ablation 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, burst-load setting, and parameter table; it does not claim observed field measurements. This keeps the batch variability experiment inexpensive while preserving a rerunnable factor ablation.

4. Results

The baseline mean was 0.541; the intervention mean was 0.595. The paired change was +0.053, with a 95% interval from +0.051 to +0.056. In the prespecified adverse slice, the change was +0.043.

The machine-readable artifact `experiments/01-R05-079.json` contains all 72 paired records for battery quality control. Consequently, the +0.053 result can be recomputed directly under the burst-load setting rather than inferred from prose.

5. Discussion

The result identifies a falsifiable direction and preserves the conditions needed to retest it. For battery quality control under burst-load, the sign of the defect-screening yield change remained positive in both the full set and the late-arriving block. This supports a focused follow-up on batch variability using measured inputs and the same factor ablation 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 late-arriving block, and the factor ablation 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 burst-load generator. A real-data study should retain batch variability and the late-arriving block 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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