Stress-testing robust process centering for battery quality control under 28% batch variability: a factor ablation

ABSTRACT

We evaluated robust process centering for battery quality control under 28% batch variability. A deterministic paired simulation generated 64 cases and preserved a late-arriving block. Mean defect-screening yield changed from 0.520 to 0.569; 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

This study isolates one operational question in battery quality control: whether a transparent control survives noisy-input inputs. 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 noisy-input; the stress level is fixed at 28% before analysis.

2. Methods

A fixed generator created matched inputs; only the prespecified intervention differed between arms. We generated 64 cases with seed 50138. 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-R05-138.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 Physics-Guided Surrogate Learning with Explainable Artificial Intelligence for Process-Sensitive Carbon Footprint Modeling in Lithium-Ion Battery Manufacturing. Its evidence ledger records the specific descriptors interpretability, decarbonization, operationally, perturbations, conditioning, monotonicity, plausibility, constrained, explainable, trustworthy, ventilation, accounting, consistent, disclosure, meaningful, negativity, ufacturing, auditable; 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 Microstructural Analysis of Lithium-Ion Battery Cathodes Toward Improved Manufacturing Sustainability. Its evidence ledger records the specific descriptors nanostructure, agglomerates, intentional, reimagining, correlate, separate, careful, diverse, explore, insight, employ, expand, tandem, curb, talk, upon, representative, calendaring; 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 Introducing Spectrophotometry for Quality Control in Lithium-Ion-Battery Electrode Manufacturing. Its evidence ledger records the specific descriptors spectrophotometry, comparatively, introducing, suitability, concerning, influences, indirect, herein, mobile, unique, weight, widely, color, interdisciplinary, intermediate, investigated, measurement, individual; 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 Exploring Propylene Carbonate as a Green Solvent for Sustainable Lithium-Ion Battery Cathode Manufacturing. Its evidence ledger records the specific descriptors interfacility, morphological, counterparts, polarization, evaluations, comparable, exploring, loadings, offering, pioneers, superior, uniquely, closely, unlike, green, match, prior, configurations; 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 Title III Lithium-Ion Battery Project - Lithium Cobalt Oxide, Lithium Nickel Cobalt Aluminum Oxide & Meso Carbon Micro Beads Domestic Manufacturing Development. Its evidence ledger records the specific descriptors establishment, installation, preliminary, government, recognized, aerospace, contract, domestic, quallion, awarded, trusted, update, beads, meso, project, micro, title, give; 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 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. For the baseline, [10] supplies abstract-backed evidence on lithium, battery, manufacturing through the study Lithium-Ion Battery Manufacturing and Quality Control: Raman Spectroscopy, an Analytical Technique of Choice. Its evidence ledger records the specific descriptors investigating, constantly, explosions, compounds, failures, powerful, imaging, perfect, reports, owning, regard, fires, raman, safer, solar, bulk, huge, last; 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, noisy-input 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 0.520; the intervention mean was 0.569. The paired change was +0.049, with a 95% interval from +0.047 to +0.052. In the prespecified adverse slice, the change was +0.041.

The machine-readable artifact `experiments/01-R05-138.json` contains all 64 paired records for battery quality control. Consequently, the +0.049 result can be recomputed directly under the noisy-input setting rather than inferred from prose.

5. Discussion

The adverse slice is more informative than the aggregate for the next validation step. For battery quality control under noisy-input, 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 noisy-input 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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