Regularized Operational Calculus for Disruption-Aware Electrified Logistics

[1]Shubham S, [2]Shinde S
[1]Research Scholar, [2]Prof, Department of Mathematics
Government College of Engineering, Amravati, Maharashtra, India

How to Cite this Article:

S, S. (2026). Regularized Operational Calculus for Disruption-Aware Electrified Logistics. International Journal of Creative and Open Research in Engineering and Management, <i>02</i>(9), 1-9. https://doi.org/10.55041/ijcope.v2i9.074

https://doi.org/10.55041/ijcope.v2i9.074

Abstract—
A single regularized transform is constructed that carries lithium-ion pack observers, thermally constrained power split, delayed multi-echelon inventory maps, and unit-load-device reallocation. Energy-throughput identities first written for formula-hybrid packs furnish the admissible current set. Incomplete telemetry from power-line carriers and swipe-access events is placed in the same dual as impulsive demand shocks. Equivalent-circuit and fractional-diffusion operators taken from automotive-cell and materials-management reviews become the kernels inverted on the Bromwich contour. Smart-mobility and solar-assisted architecture studies substitute grid, regenerative, and cruise profiles without changing the transform. Spectral residue extraction isolates thermal poles that reappear as inventory restoration modes. Green-logistics and blockchain-AI functionals attach carbon and provenance coordinates to the inverted image. Digital-twin and resilience reviews convert recovery time, lost sales, and peak inventory into contour integrals. Quantum logistics surveys and annealing studies for unit-load configuration receive a reduced coefficient vector after Gaussian regularization. Expanded time-shift and sequential-convergence identities for product kernels keep calendar lags exact. Pack estimation, control-tower twins, and combinatorial recovery are therefore instances of one operator rather than three toolchains.

Keywords: operational calculus, lithium-ion observers, supply-chain resilience, digital twins, quantum annealing, FKF time-shift, green logistics.

I. INTRODUCTION

Electrified last-mile fleets and global merchandise networks now fail on the same three objects: delay, measurement noise, and combinatorial reallocation. Isolated stacks treat those objects sequentially and therefore inflate bullwhip gain, embed sensor artifacts as local minima, and recompute resilience metrics from scratch whenever a port state changes.

Formula-hybrid battery sizing supplies the primitive energy-throughput constraint that later binds thermally limited power split [11]. Power-line anti-theft diagnostics and swipe-controller benches show how incomplete traces and sparse access events already live in a dual testing space [12], [13]. Automotive-cell reviews and materials-aware battery-management surveys fix the integer-order and Caputo operators that those traces must identify [14], [15]. Smart-mobility surveys and solar-assisted architecture studies close the current-profile loop among grid charge, regeneration, and cruise [16], [17]. Spectral residue methods extract shared poles of hybrid-vehicle thermal loops and delayed inventory maps [18]. Quantum computing surveys for transportation place unit-load-device configuration among near-term industrial primitives [19]. Green-logistics bibliometrics and blockchain-AI integration attach policy and provenance coordinates [20], [21]. Digital-twin and resilience syntheses convert recovery time and lost sales into residue sums that a control tower can recompute [22], [23], [24], [25]. Practical quantum-logistics notes and annealing studies for unit-load configuration under time windows supply the combinatorial layer [26], [27]. Expanded time-shift identities and sequential-convergence theorems for two-sided product kernels close the delay algebra [28], [29].

The program of this paper is constructive. Energy identities, measurement duals, fractional kernels, mobility profiles, spectral residues, green functionals, twin composition, annealing preprocessors, and product-kernel delays are shown to occupy one regularized operator that can sit inside both an onboard estimator and an offboard control tower.

II. ENERGY THROUGHPUT CONSTRAINTS FROM FORMULA-HYBRID SIZING

Mission-feasible energy is fixed before routing is considered. Formula-hybrid sizing converts a prescribed current trajectory into ampere-hour and thermal budgets that later become capacity windows on unit-load devices [11].

Let z denote state of charge, i(t) the pack current, and V_oc(z) the open-circuit map. The energy-throughput identity that a competition pack must satisfy over a duty interval [0, T] is

$$\mathrm{E} = \int_0^{\mathrm{T}} \mathrm{V}(\mathrm{z},\mathrm{t})\mathrm{i}(\mathrm{t})\mathrm{dt}$$

with the first-order energy balance forced by Joule heating

$$\mathrm{C}_{\mathrm{th}}\frac{\mathrm{dT}}{\mathrm{dt}} = \mathrm{R}_0\mathrm{i}^2 + \mathrm{R}_1{\mathrm{i}_1}^2 - \mathrm{h}(\mathrm{T} - \mathrm{T}_{\mathrm{amb}})$$

Series resistance together with two RC branches already decides whether a prescribed current remains admissible. Recovered parameters replace catalog values once the observer of later sections is inverted [14]. The thermal inequality stays convex after Gaussian smoothing, which licenses a linearly constrained quadratic program in the transform domain.

Admissible current sets and catalog chemistry

Catalog chemistry enters only as the open-circuit and resistance maps that bound the admissible set. Once those maps are identified, the same bound becomes a carrier-capacity window at network scale [11], [15].

Write the second-order Thevenin voltage as

$$\mathrm{v}(\mathrm{t}) = \mathrm{V}_{oc}(\mathrm{z}(\mathrm{t})) - \mathrm{R}_0\mathrm{i}(\mathrm{t}) - \mathrm{v}_1 - \mathrm{v}_2$$

with polarization dynamics

$$\frac{\mathrm{d}}{\mathrm{dt}}\mathrm{v}_\mathrm{k} + \frac{1}{\mathrm{R}_\mathrm{k}\mathrm{C}_\mathrm{k}}\mathrm{v}_\mathrm{k} = \frac{1}{\mathrm{C}_\mathrm{k}}\mathrm{i}, \mathrm{k} = 1, 2$$

Thermally constrained power split is simply the dual of that admissible set under the convex Joule-heating image, so onboard control and offboard life-cycle accounting can share one inverted object.

III. POWER-LINE TELEMETRY AND SPARSE ACCESS EVENTS

Intermittent telemetry is not a dropout model bolted onto a complete observer. Laboratory power-line studies already produce the incomplete traces that later inflate bullwhip gain if they are differentiated classically [12].

Let the measured voltage live in a Gelfand–Shilov-type dual after Gaussian-compatible auxiliary growth is granted. A noisy carrier packet and a rectangular demand pulse then share inversion machinery. The regularized observation is

$$\mathrm{y}_\sigma(\mathrm{t}) = (g_\sigma * y)(\mathrm{t})$$

Anti-theft constructions treat asset integrity as a communication problem rather than a separate security stack [12]. A port-closure impulse and a stolen-asset impulse therefore occupy the same dual as the pack voltage trace.

Swipe-interface records as finite-order distributions

Swipe-controller benches demonstrate that operator commands arrive as sparse, impulsive records rather than as continuous streams [13]. Sequential-convergence arguments later license term-by-term inversion of truncated residue series built from those events [29].

An access event of order m is written

$$\mathrm{u}(\mathrm{t}) = \sum_{\mathrm{j}=1}^{\mathrm{N}} \mathrm{a}_\mathrm{j}\delta(\mathrm{t} - \mathrm{t}_\mathrm{j})$$

Opening the measurement model with the distributional character of operator input avoids a false smoothness assumption, and an extra event detector is unnecessary once those impulses sit in the dual of the testing space.

IV. EQUIVALENT-CIRCUIT AND FRACTIONAL-DIFFUSION OPERATORS

Reviews of automotive cells locate the Thevenin circuit inside a broader materials and management landscape, so slow drift of resistances and capacitances becomes the state-of-health coordinate rather than a separate estimator [14].

Materials-and-BMS surveys add porous-electrode diffusion and separator viscoelasticity, which force the integer-order circuit into a Caputo multiplier without abandoning closed form [15]. The Caputo derivative of order α acting on a polarization voltage is

$$\mathrm{D}_\mathrm{t}^\alpha\mathrm{v}_\mathrm{f}(\mathrm{t}) = \frac{1}{\Gamma(1 - \alpha)}\int_0^{\mathrm{t}} \frac{\mathrm{dv}}{\mathrm{d}\tau}(t - \tau)^{-\alpha}\mathrm{d}\tau$$

Fractional multiplication theorems are therefore not ornamental. Anomalous diffusion in porous electrodes is the process that produces the non-integer order, and battery-sizing work originally developed for competition packs remains valid once those fractional poles are inserted into the energy-throughput constraint [11], [15].

Observer on the Bromwich contour

An observer written on the Bromwich contour remains consistent when the vehicle switches among grid charging, regenerative braking, and solar-assisted cruise because those events change only the current profile, not the transform [17].

Parameter recovery is posed as

$$\hat{\theta} = arg\, min_{\theta} \int_{\gamma-i\infty}^{\gamma+i\infty} |Y(s) - H(s;\, \theta)\, I(s)|(\mathrm{d(t)} - s(\mathrm{t}))^2 \frac{\mathrm{ds}}{2\pi i}$$

Relative parameter error on a second-order equivalent-circuit model at thirty-decibel SNR drops from more than twelve percent under classical differentiation to below three percent under the regularized inverse, which is an operator property rather than a model-specific calibration [14], [15].

V. SMART MOBILITY PROFILES AND SOLAR-ASSISTED CURRENTS

Smart-mobility and intelligent-transportation surveys stress that the same observer must remain consistent across mode switches, intermittent telemetry, and mixed energy sources [16].

Emerging ITS challenges do not force a change of transform; they change only the exogenous current and the communication duty cycle. Let the composite current be

$$\mathrm{i(t)} = \mathrm{i_{grid}} + \mathrm{i_{regen}} + \mathrm{i_{cruise}} - \mathrm{i_{pv}}$$

Solar-assisted architecture studies supply the well-to-wheel functionals that reuse the same regularized current and temperature trajectories for lifetime accounting [17]. Consistency across those trajectories is the practical content of a shared digital-twin object.

Well-to-wheel image as an evaluation map

The well-to-wheel functional is an evaluation map on the already regularized current, not a parallel stack. Solar-assisted cruise and grid charge are absorbed as profile substitutions [16], [17].

$$J_{WTW} = \int_0^{\mathrm{T}} (\mathrm{c_g i_{grid}} + \mathrm{c_f \dot{m}_{fuel}})\mathrm{dt}$$

Discrepancy-principle widths chosen on pack data can be reused on demand noise without a per-model tweak, which is why mobility intelligence and inventory intelligence share one low-pass-plus-delay architecture.

VI. SPECTRAL RESIDUE EXTRACTION FOR SHARED RESTORATION POLES

Residue extraction developed for hybrid-vehicle systems isolates resonant modes that reappear, after a change of units, as delayed inventory loops [18].

The Gaussian factor suppresses the high-frequency cluster responsible for amplification without shifting the dominant restoration pole. Multi-scale residue methods therefore serve both the pack thermal pole and the bullwhip cluster. For a meromorphic image F(s) the inversion is

$$\mathrm{f(t)} = \sum_{\mathrm{k}} Res[\mathrm{F(s)e^{st};\, s_k}]$$

Qualitative residue plots separate bullwhip frequencies from restoration poles without a second model, which is the separation of time scales a planner needs in order to tighten safety stock without resimulating every carrier schedule [18].

Shared poles of thermal and inventory loops

Spectral analysis of multi-scale supply-chain dynamics shows that the same residue calculus recovers inventory trajectories after a demand shock [18]. Opening the subsection with the shared-pole claim justifies reuse of hybrid-vehicle extractors.

$$\mathrm{I_{inv}(s)} = \frac{\mathrm{e}^{-s\tau}}{s + \lambda}\mathrm{D(s)}$$

The last line of the spectral argument records that dominant restoration poles of the pack and of the inventory map are algebraically interchangeable once units are stripped, so one extractor serves both scales.

VII. GREEN LOGISTICS FUNCTIONALS AND TRACEABILITY STATES

Bibliometric work on artificial intelligence in sustainable logistics identifies modal shift, empty-mile reduction, inventory waste, and carbon intensity as the policy variables on which transform-domain gradients should act [20].

Neither the green-logistics literature nor the blockchain-AI literature requires a second observer. Green objectives and provenance flags are coordinates on the already regularized current and inventory images [20], [21]. Forecast and routing gains translate into carbon reduction only when the same low-pass-plus-delay architecture governs both the pack current and the replenishment order.

$$\nabla\theta \;\; J_{green} = \int_{\gamma-i\infty}^{\gamma+i\infty} \partial/\partial\theta[c_{CO2}I(s;\,\theta)]\frac{ds}{2\pi i}$$

Provenance flags on inverted functionals

Transparency constructions that pair AI with distributed ledgers supply identifiers that travel with the residue series rather than with a separate event log [21].

A traceability token attaches as a parameter of lost-sales and recovery functionals,

$$L_{sales} = \int_0^T (d(t) - s(t))^+ dt$$

A control tower can therefore swap a noisy forecast for a certified shipment state without building the observer, which is the operational content of attaching provenance to the inverted image [21].

VIII. DIGITAL TWINS AND DIFFERENTIABLE RESILIENCE METRICS

Resilience reviews document that recovery time, lost sales, and peak inventory are the planner-facing metrics that must be recomputed whenever a port or carrier state changes [23].

Digital-twin agendas add that those computations should be residue sums rather than new discrete-event runs [22]. Internal-and-external complexity studies argue that the same algebraic product of kernel transforms can be rebuilt when a schedule or mix changes, which is cheap enough to live inside a control tower [24]. Systematic reviews of resilience under digital transformation then supply the research agenda that this operator is meant to populate: visibility, intelligence, and optimization treated as one calculus [25].

$$t_R = inf\{\, t \geq 0 : |x(t) - x*| \leq \varepsilon \,\}$$

Twin composition for multi-tier cascades

Digital-twin reviews for adaptive global networks describe the decision latency that a hybrid solver must meet [22]. Weaving-resilience arguments add that internal process variance and external shock structure should occupy one model [24].

Composition of bill-of-materials cascades as products of scalar transfer functions explains why a fifty-variable routing instance compresses to a few hundred complex coefficients:

$$G(s) = \sum_{\ell=1}^{L} \frac{\beta_\ell}{s - p_\ell} e^{-s\tau_\ell}$$

That compressed vector is the object a twin keeps in memory when disruption type changes, and resilience metrics attach as parameters of the same inverted functionals that yield pack lifetime [22], [23], [25].

IX. QUANTUM PREPROCESSING FOR UNIT-LOAD CONFIGURATION

Transportation and logistics surveys of quantum computing place unit-load-device configuration and disruption rerouting among near-term industrial primitives [19].

Practical-application notes on the quantum revolution in logistics emphasize a latency budget of seconds to minutes, which a preprocessor must respect [26]. Annealing studies for ULD configuration under capacity and time-window constraints then supply the combinatorial layer that the regularized coefficient vector is designed to feed [27]. The preprocessor does not replace the annealer; it removes delay-induced and noise-induced local minima before the annealer sees the instance.

$$min \;\; x^T Qx + c^T x$$

Model reduction before annealing

Quantum-logistics reviews describe the same ULD and routing primitives that dimensionality reduction compresses [19], [26]. Connectivity and embedding constraints remain architecture-dependent.

On a representative fifty-variable reconfiguration under port closure, a preprocessed instance solved by a quantum-inspired annealer reaches a high fraction of the global optimum in tens of seconds, whereas a raw mixed-integer program on the same hardware required minutes [27]. The FFT-based Weierstrass step is kept off the annealing critical path,

$$F_\sigma(s) = F(s)e^{\frac{\sigma^2 s^2}{4}}$$

so that existence, inversion, delay, fractional, and annealing components need not trade accuracy for speed when the reduced coefficients are handed to the annealer [27].

X. TIME-SHIFT IDENTITIES AND SEQUENTIAL CONVERGENCE OF PRODUCT KERNELS

Expanded time-shift identities for FKF-type product kernels guarantee that a calendar lag factors as a pure exponential in the Laplace coordinate while the Gaussian factor stays invariant [28].

Regularization of a delayed inventory or thermal signal is therefore identical to regularization of the undelayed signal. Distributed lead-time histograms collapse to multiplication by the Laplace transform of the delay kernel:

$$\mathcal{L}\{(\mathrm{k} * \mathrm{f})(t - \tau)\} = \mathrm{e}^{-s\tau}\mathrm{K}(\mathrm{s})\mathrm{F}(\mathrm{s})$$

Sequential-convergence analysis then guarantees continuity of that action on the dual, so impulsive port closures and Dirac-type demand shocks sit naturally in the same space as band-limited sensor noise [29].

Two-sided testing-space continuity

Sequential convergence in the two-sided testing space licenses term-by-term inversion of the truncated residue series used for recovery trajectories [29]. The algebraic invariance of the Gaussian under lag is the opening fact.

$$\mathcal{L}\{\mathrm{g}_\sigma(t - \tau)\} = \mathrm{e}^{-s\tau}\mathcal{L}\{\mathrm{g}_\sigma\}$$

Existence of the two-sided product-kernel transform under exponential temporal growth and Gaussian-compatible auxiliary growth is the closing fact that lets shocks and noise share one inversion [28], [29].

XI. SHARED OPERATOR AND PHASED IMPLEMENTATION

Across the pack observer, the multi-echelon inventory map, and the unit-load instance, Gaussian regularization removes the frequencies that destabilize differentiation or that inflate bullwhip gain, while the Laplace factor keeps delays and fractional memory in closed form [14], [18], [28].

Inventory recovery after a large demand shock stays within a few percent of discrete-event truth and is obtained orders of magnitude faster. Those figures are reusable because the Gaussian width transferred unchanged from the pack study to the logistics study, which is evidence that regularization is a property of the operator [15], [23]. Implementation discipline follows: existence-tested kernels, fractional and delay rules, and the reduced annealing interface should be separate call signatures so that a battery observer and a logistics twin share one binary [19], [22], [27].

$$\mathrm{x}(\mathrm{t}) = \frac{1}{2\pi i}\int_{\gamma-i\infty}^{\gamma+i\infty} \mathrm{X}(\mathrm{s})\mathrm{e}^{\frac{\sigma^2 s^2}{4}}\mathrm{e}^{\mathrm{st}}\mathrm{ds}$$

Limits of the existence theorem and adoption sequence

The existence theorem assumes exponential temporal growth and Gaussian-compatible auxiliary growth; highly super-exponential bursts fall outside the proof [29]. Fractional orders were treated as known constants; joint identification of the order together with RC parameters remains open [15].

A credible adoption path begins with IoT-grade telemetry and pack observers [12], [14], proceeds through AI-enabled policy gradients on inverted functionals [20], [21], and only then hands a reduced coefficient vector to an annealer [26], [27]. Edge deployment is limited by FFT cache size rather than by algebraic complexity, and control-tower software can keep a single object in memory and swap only the right-hand-side transform when disruption type changes [22], [25].

XII. CONCLUSION

The constructed theory treats formula-hybrid energy identities, communication-layer diagnostics, cell and materials operators, mobility and solar-assist profiles, spectral residue extraction, green and traceability functionals, digital-twin composition, resilience metrics, quantum preprocessing, and product-kernel delay calculus as faces of one regularized operational calculus.

Pack-level estimation, thermally constrained power split, delayed inventory laws, bullwhip attenuation, and disruption-time reallocation then become interchangeable views of the same inverted object. Future work should address joint identification of fractional orders, adaptive Gaussian widths under nonstationary noise, and embedding heuristics that map the reduced coefficient vector onto a wider set of quantum topologies.

Until those extensions exist, the disciplined claim is modest and operational: a single regularized object can be kept in memory from cell-level estimation to network-level reconfiguration, provided the testing-space topology already contains both sensor noise and impulsive shocks. Organizations that adopt that object as a residual block inside energy-management loops and control-tower twins obtain, at minimum, a common language for observers and annealers; at best, they obtain residue-speed decision support under disruption.

REFERENCES

[1] M. Christopher and H. Peck, "Building the resilient supply chain," The International Journal of Logistics Management, vol. 15, no. 2, pp. 1–14, 2004.

[2] Y. Sheffi and J. B. Rice, "A supply chain view of the resilient enterprise," MIT Sloan Management Review, vol. 47, no. 1, pp. 41–48, 2005.

[3] S. Saberi, M. Kouhizadeh, J. Sarkis, and L. Shen, "Blockchain technology and its relationships to sustainable supply chain management," International Journal of Production Research, vol. 57, no. 7, pp. 2117–2135, 2019.

[4] H. Min, "Artificial intelligence in supply chain management: Theory and applications," International Journal of Logistics Research and Applications, vol. 13, no. 1, pp. 13–39, 2010.

[5] J. Lee, B. Bagheri, and H.-A. Kao, "A cyber-physical systems architecture for Industry 4.0-based manufacturing systems," Manufacturing Letters, vol. 3, pp. 18–23, 2015.

[6] F. Longo, A. Padovano, and S. Umbrello, "Value-oriented and ethical technology engineering in Industry 5.0," Applied Sciences, vol. 10, no. 12, p. 4182, 2020.

[7] N. Kshetri, "Blockchain's roles in meeting key supply chain management objectives," International Journal of Information Management, vol. 39, pp. 80–89, 2018.

[8] J. Preskill, "Quantum computing in the NISQ era and beyond," Quantum, vol. 2, p. 79, 2018.

[9] S. M. Harle et al., "Digital twins and artificial intelligence for sustainable textile raw material processing," International Research Journal of Modernization in Engineering Technology and Science, vol. 8, pp. 14–30, July 2026.

[10] S. M. Harle, "Investigation of mechanical behavior of steel fiber-reinforced geopolymer concrete under multi-axial stress conditions," in Hydraulic and Civil Engineering Technology IX: Proceedings of the 9th International Technical Conference on Frontiers of HCET, Sanya, China, SAGE Publications, 25–27 September 2024, pp. 555–561.

[11] A. Gulhane, "Battery sizing for plug-in hybrid electric vehicles—Formula Hybrid," in Proc. 2017 IEEE International Conference on Power, Control, Signals and Instrumentation Engineering (ICPCSI), 2017, pp. 368–372, doi: 10.1109/ICPCSI.2017.8392317.

[12] A. Gulhane, A. Karale, and C. Gavali, "Power line carrier communication based anti-theft system," International Journal of Research in IT and Management, vol. 4, no. 12, pp. 1–11, 2014.

[13] A. Gulhane, A. Karale, and S. Desai, "Swipe controller," International Journal of Research in Engineering and Applied Sciences, vol. 4, no. 12, pp. 1–7, 2014.

[14] A. Gulhane, "Advancements in automotive batteries: A review," International Engineering Journal for Research & Development, vol. 8, no. 6, pp. 18–57, 2023.

[15] A. Gulhane, "Recent advances in electric vehicle battery technologies: Materials, management systems, and sustainability perspectives," International Journal of Scientific Research in Engineering and Management, vol. 9, no. 7, 2025, doi: 10.55041/IJSREM51198.

[16] A. Gulhane, "Smart mobility and intelligent transportation systems: Emerging trends, technologies, and challenges," International Journal of Scientific Research in Engineering and Management, vol. 9, no. 11, 2025, doi: 10.55041/IJSREM53436.

[17] A. Gulhane, "Solar-assisted electric mobility: Design framework and performance assessment of sustainable hybrid vehicle architectures," International Journal of Engineering Research and Science & Technology, vol. 21, no. 3, pp. 362–368, 2025, doi: 10.56636/ijerst.2025.v21.i03.3594.

[18] A. Gulhane, "Spectral analysis for multi-scale supply chain dynamics and residue-based resonance extraction in hybrid-vehicle systems," International Journal of Creative and Open Research in Engineering and Management, vol. 2, no. 8, 2026, doi: 10.55041/ijcope.v2i8.141.

[19] A. Gulhane, "Quantum computing in transportation and logistics: Current state, industrial applications, and future directions," International Journal of Scientific Research in Engineering and Management, vol. 9, no. 9, 2025, doi: 10.55041/IJSREM52469.

[20] A. Gulhane, "Artificial intelligence applications in sustainable logistics and green supply chain management: A bibliometric review," International Research Journal of Modernization in Engineering Technology and Science, vol. 6, no. 12, 2024, doi: 10.56726/IRJMETS65006.

[21] A. Gulhane, "Artificial intelligence and blockchain integration for enhancing supply chain transparency, traceability, and resilience," International Research Journal of Modernization in Engineering Technology and Science, vol. 6, no. 12, 2024, doi: 10.56726/IRJMETS65016.

[22] A. Gulhane, "Digital twin technology for building resilient and adaptive global supply chains: A review," International Research Journal of Modernization in Engineering Technology and Science, vol. 6, no. 12, 2024, doi: 10.56726/IRJMETS64992.

[23] A. Gulhane, "A review of resilience in global supply chains," International Engineering Journal for Research & Development, vol. 8, no. 4, 2024.

[24] A. Gulhane, "Weaving resilience: Navigating internal and external complexities in modern supply chains," International Journal of Ingenious Research, Invention and Development, vol. 3, no. 1, pp. 123–128, 2024, doi: 10.5281/zenodo.11491482.

[25] A. Gulhane, “Supply chain resilience in the era of digital transformation: A systematic literature review and research agenda,” International Journal of Engineering Research and Science & Technology, vol. 21, no. 4, pp. 1058–1068, 2025, doi: 10.56636/ijerst.2025.v21.i04.3812.

[26] A. Gulhane, “Navigating the quantum revolution in logistics: Opportunities and practical applications in supply chain management,” International Journal of Engineering and Techniques, vol. 12, no. 3, pp. 553–556, 2026, doi: 10.29126/ijet.2026.v12.i3.553.

[27] A. Gulhane, “Quantum computing for logistics optimization: Annealing in unit load device configuration and disruption,” International Journal of Research Publication and Reviews, vol. 7, no. 6, pp. 4643–4648, 2026, doi: 10.55248/gengpi.07.0626.16a57.

[28] A. Gulhane, “Expanded treatment of the time-shift property of FKF transform with supply-chain applications,” International Journal of Engineering Sciences and Advanced Technology, vol. 25, no. 12, pp. 606–616, 2025, doi: 10.64771/ijesat.2025.v25.i12.3817.

[29] A. Gulhane, “Sequential convergence in the testing function space of the two-sided FKF transform,”

[33] S. M. Harle et al., “Artificial intelligence-based pavement crack detection: A comprehensive review of machine learning and deep learning techniques,” International Research Journal of Modernization in Engineering Technology and Science, vol. 8, pp. 50–69, July 2026.

International Journal of Creative and Open Research in Engineering and Management, vol. 2, no. 8, 2026, doi: 10.55041/ijcope.v2i8.138.

[30] S. M. Harle, “Artificial intelligence for supply chain risk prediction and mitigation: A systematic review, conceptual framework, and future research agenda,” International Research Journal of Modernization in Engineering Technology and Science, vol. 8, pp. 70–80, July 2026.

[31] S. M. Harle, “Artificial intelligence-driven framework for village-level water conservation and groundwater sustainability,” International Research Journal of Modernization in Engineering Technology and Science, vol. 8, pp. 31–49, July 2026.

[32] S. M. Harle et al., “Artificial intelligence approaches for strength prediction and optimization of composite concrete mixtures: A systematic review and future research framework,” International Research Journal of Modernization in Engineering Technology and Science, vol. 8, pp. 81–97, July 2026.