



Quantum Annealing for Resilient EV Battery Systems

Padmaja¹, Abhilasha G²

¹ Mathematics/ GCOEA/ Amravati

² Business Analyst / USA

1gulhane.padmaja@rediffmail.com



[https://doi.org/ 10.55041/ijst.v2i6.213](https://doi.org/10.55041/ijst.v2i6.213)

Cite this Article: Padmaja, & G, A. (2026). Quantum Annealing for Resilient EV Battery Systems. International Journal of Science, Strategic Management and Technology, 02(6). <https://doi.org/10.55041/ijst.v2i6.213>

License:  This article is published under the Creative Commons Attribution 4.0 International License (CC BY 4.0), permitting use, distribution, and reproduction in any medium, provided the original author(s) and source are properly credited.

Abstract-

This paper introduces the LW transform, which fuses the classical Laplace transform with Weierstrass Gaussian smoothing to embed built-in regularization for dynamic systems. We present a corrected existence theorem, an explicit inversion formula, a convolution theorem, fractional-order operational calculus, and stable numerical methods. These advances enable efficient, robust solutions to linear and integro-differential equations even with noisy or incomplete data.

The framework is applied to electric vehicle battery systems for lithium-ion modeling, parameter estimation, SoC/SoH analysis, and hybrid optimization under thermal constraints. It is further applied to resilient supply chains to model inventory dynamics with lead time delays, disruption recovery, and bullwhip-effect mitigation. The approach yields computationally tractable tools for system modeling and digital twins. Future work focuses on hybrid quantum classical methods that leverage quantum annealing for largescale logistics optimization.

Keywords- lithium ion battery modeling; electric vehicle systems; supply chain resilience;

operational calculus; distributional transforms; hybrid quantum classical optimization; disruptions; bullwhip effect; fractional calculus

I. INTRODUCTION

Integral transforms rank among the most powerful analytical tools in science and engineering, converting complex differential, integral, and delay equations into simpler algebraic forms. The Laplace transform has long been central to control systems and dynamic modeling, while the Weierstrass transform supplies effective Gaussian smoothing grounded in approximation theory. Their composition the LW transform delivers built in regularization in an auxiliary dimension together with temporal analysis, making it especially attractive for systems that must handle both evolution and noise or uncertainty. The rapid growth of EVs and the rising frequency of global supply chain disruptions have created an urgent need for frameworks that manage coupled dynamics, noisy measurements, and abrupt parametric shifts. Lithium-ion battery modeling, state estimation, thermal management, and hybrid power-flow analysis involve differential and integro-differential equations subject to sensor noise. Resilient supply chain modeling likewise



requires tools for inventory dynamics under stochastic lead times, sudden disruptions, and secondary effects such as the bullwhip phenomenon.

Earlier foundational work on the LW transform provided basic existence conditions and operational properties but left several important gaps: a complete and rigorously justified inversion procedure, convolution properties for memory effects, fractional order extensions, and most critically demonstrations of practical value in high impact contemporary domains. Conventional approaches typically treat dynamics and smoothing separately, leading either to loss of analytical tractability or insufficient regularization against real world noise.

This paper addresses these gaps through several key advances: a corrected existence theorem, an explicit inversion formula, a convolution theorem, fractional order operational calculus, and stable numerical methods. These developments are applied to lithium-ion battery systems for parameter estimation, SoC/SoH analysis, and thermal management (with natural handling of sensor noise) and to resilient supply chain models involving inventory dynamics, lead time delays, disruption recovery, and bullwhip mitigation. A particularly promising direction integrates the LW transform's smoothing and dimensionality-reduction strengths with quantum annealing solvers for combinatorial optimization subproblems in logistics network configuration and disruption response planning. This hybrid quantum-classical approach builds directly on recent quantum methods for supply chains while exploiting the LW framework's regularization and computational tractability.

By forging a direct and rigorous connection between advanced transform theory embodied in the LW transform and its Mikusiński-style operational calculus extensions and the pressing engineering challenges in energy storage, automotive systems, and resilient logistics, this work achieves a distinguished balance of theoretical novelty and tangible applied impact. The framework elegantly

unifies the precise algebraic handling of linear dynamics, constant and distributed delays, and fractional order effects (via operational rules that map differentiation to multiplication by the transform variable, delays to exponential multipliers, and convolutions to products) with the intrinsic regularization and noise-robust smoothing of the Weierstrass Gaussian kernel. This synthesis yields new existence theories in distributional settings [28], [29], [36], explicit inversion and convolution theorems, fractional order operational rules, and stable numerical discretization schemes, all while preserving computational tractability across multi physics and stochastic environments.

The resulting framework remains highly computationally efficient and is exceptionally well suited for real-time estimation tasks (such as noise-robust SoC/SoH tracking and parameter identification in lithium-ion EV batteries under thermal transients, load variations, and sensor noise), iterative optimization loops (including hybrid quantum classical pipelines that couple LW-based [17] model reduction with quantum annealing for large scale logistics problems), and high fidelity digital twin implementations. Extensive numerical validation on realistic battery equivalent circuit models and disrupted multi-echelon supply chains incorporating stochastic lead times, bullwhip propagation, and post-disruption recovery trajectories confirms superior accuracy, stability, and speed relative to classical Laplace/Fourier methods or purely data-driven baselines. In doing so, the work not only advances the frontiers of applied operational calculus but also equips engineers and system integrators analytical toolkit for sustainable mobility solutions and adaptive, disruption resilient logistics networks.

II. LITERATURE REVIEW

The theoretical foundations of integral transforms trace back to classical works on the Laplace transform and its extensions to generalized functions. Zemanian's treatise on generalized integral transformations [14] and Doetsch's comprehensive treatment [15] established rigorous frameworks for



operational calculus in distributional settings. Mikusiński's algebraic approach further enabled the treatment of differential operators as multiplication in transform domains, providing the conceptual basis for modern operational calculus extensions [6], [11], [12].

The Weierstrass transform, grounded in Gaussian kernel smoothing and approximation theory, has long served as a regularization tool for ill-posed inverse problems and noisy data. Its integration with Laplace analysis into the composite LW transform was explored in earlier contributions by the authors' group [9], [13], [22], [34], which established preliminary existence conditions and basic operational rules. However, those works left open critical questions regarding explicit inversion formulas, convolution theorems for memory kernels, fractional extensions, and most importantly convincing demonstrations of engineering impact in domains characterized by noisy sensor streams and combinatorial decision layers.

In the battery systems domain, electrochemical modeling has been dominated by the DFN framework and its SPM reduction [7, 21]. These models yield systems of partial differential equations whose real-time solution and parameter identification remain challenging under sensor noise typical of BMS. Fractional order extensions have been proposed to capture memory effects and anomalous diffusion [10], [16], [24] with reviews underscoring the need for robust, regularized estimation techniques suitable for embedded implementation. Data-driven and hybrid physics-informed neural network approaches have emerged, yet they often sacrifice interpretability or require extensive training data that may not be available during early design or under fault conditions.

Supply chain research has extensively documented the bullwhip effect [30], [34] and the value of resilience strategies under disruption. Serman's system dynamics perspective [20] highlighted feedback delays and information distortion as root causes. More recent literature advocates digital-twin

architectures for real-time visibility and adaptive control [22], while quantum and quantum-inspired methods have been applied to combinatorial subproblems such as inventory positioning, vehicle routing, and ULD configuration [2], [3], [16], [23], [25]. Ising/QUBO formulations [32] enable quantum annealing solvers to address NP-hard logistics instances, yet coupling these discrete optimizers with continuous, delayed, noisy dynamical models remains an open methodological gap.

Hybrid quantum-classical pipelines have attracted significant attention in quantum machine learning and optimization [5]. Nevertheless, few frameworks simultaneously (i) preserve exact algebraic treatment of delays and memory kernels, (ii) embed intrinsic regularization against measurement noise, and (iii) reduce dimensionality sufficiently for current quantum hardware constraints. The present work closes this gap by furnishing the missing theoretical components of the LW transform and demonstrating an end-to-end pipeline that maps regularized, delay aware algebraic models directly onto QUBO instances solvable by quantum annealers or hybrid solvers, with reconstruction of time domain decisions via stable numerical inversion.

III. THEORETICAL FOUNDATIONS AND OPERATIONAL PROPERTIES

To handle functions of limited regularity and noise typical of battery sensor data and real-time supply chain monitoring, the LW transform is formulated in Gelfand–Shilov-type testing-function spaces consisting of infinitely differentiable functions with rapid decay. This framework enables a rigorous distributional definition and inversion of the LW transform while preserving regularization, allowing it to act continuously on generalized functions arising from impulsive disruptions or sensor noise.

The associated operational calculus converts differentiation, integration, and convolution into algebraic operations with built-in Gaussian smoothing. Time differentiation maps to multiplication by powers of the transform

variable, multiplication by powers of t maps to differentiation in s , and differentiation in the auxiliary variable corresponds to multiplication by a linear factor inside the integral. These rules reduce linear differential and delay equations with polynomial coefficients to algebraic or lower order equations in the transform domain, directly applicable to equivalent circuit battery models and supply chain models with distributed lead times.

The framework is particularly effective for stable SoH estimation and parameter identification in electrochemical batteries, inversion of noisy delay differential equations in logistics, and regularization of transcendental transfer functions in PDE based observers and smart-grid demand response. It satisfies a convolution theorem for memory effects and operational rules for Caputo and Riemann–Liouville fractional derivatives of arbitrary order.

Key Operational Properties

The LW transform of a causal function $f(t)$ is defined as the composition of the classical Laplace transform in the time variable t and Gaussian smoothing in an auxiliary coordinate ξ :

$$U(s, \xi) = LW\{f(t)\}(s, \xi) = \int_0^\infty e^{-s t} (G_\sigma * f)(t, \xi) dt,$$

where $G_\sigma(\xi) = (2\pi\sigma^2)^{-1/2} \exp(-\xi^2 / (2\sigma^2))$ is the Gaussian kernel of width $\sigma > 0$.

This construction endows the transform with both the powerful algebraic machinery of operational calculus and the smoothing/regularization properties of the Weierstrass transform. The following operational properties are central to the hybrid optimization framework

IV. HYBRID INTEGRATION WITH QUANTUM ANNEALING

A particularly powerful extension couples the transform with quantum annealing to address large-scale combinatorial optimization problems that arise in resilient logistics, energy storage, and automotive systems. The Gaussian (Weierstrass) kernel supplies natural regularization against sensor noise, demand variability, and modeling uncertainty while

simultaneously performing dimensionality reduction an essential feature when mapping problems onto quantum hardware with limited qubit resources. At the same time, the Laplace component converts time derivatives, constant and distributed delay operators, and memory kernels into simple algebraic multiplications in the transform domain. The resulting lower-dimensional, regularized problem formulated in the joint (s, ξ) -domain is then mapped to a combinatorial optimization task, typically expressed as a Quadratic Unconstrained Binary Optimization (QUBO) problem or an Ising Hamiltonian, which can be solved efficiently by a quantum annealer or a quantum-inspired classical solver. Optimal solutions obtained in the transform domain are subsequently reconstructed in the original time domain through numerical inversion of the LW transform, yielding actionable decisions such as optimal inventory policies, battery charge schedules, or ULD configurations under disruption.

The complete hybrid pipeline is illustrated in Figure 1. After the LW transform reduces the original delayed dynamical system to a regularized algebraic problem, the objective function (e.g., minimize total logistics cost or maximize supply chain resilience subject to battery SoC/SoH and inventory constraints) together with all business and physical constraints is discretized or relaxed into QUBO form. The quantum annealer then searches for near optimal binary solutions at a scale and speed that classical branch and bound methods struggle to match for large, non convex instances. Because the Gaussian smoothing is already embedded in the transform, the recovered solutions are inherently robust to noise, eliminating the need for separate regularization stages that often degrade solution quality in purely data-driven or classical optimization pipelines.

This approach is particularly advantageous for problems that combine continuous dynamics with discrete decisions under uncertainty precisely the setting encountered in resilient supply chain optimization under disruption

(bullwhip mitigation, recovery scheduling, multi-echelon inventory positioning), aviation ULD configuration and disruption management, and real-time EV fleet battery charging optimization subject to thermal, grid, and delay constraints. The dimensionality reduction and built in regularization provided by the Weierstrass component make previously intractable industrial instances amenable to quantum-accelerated solution, while the exact algebraic treatment of delays and memory kernels preserves modeling fidelity that would be lost under conventional time discretization.

addresses both issues simultaneously: the Laplace component converts the retarded DDEs into simple algebraic multiplication factors (e.g., e^{-st} for constant delays), while the Gaussian (Weierstrass) kernel provides built-in damping of sensor noise typical in BMS temperature, voltage, and current measurements. After this reduction, the resulting continuous thermal and electrochemical predictions feed directly into Quadratic Unconstrained Binary Optimization (QUBO) formulations solved by quantum annealers or hybrid solvers. This unified framework enables three strategically important classes of discrete decisions:

Optimal cooling circuit scheduling and actuator configuration under thermal delays. The LW reduced model supplies accurate future temperature trajectories that are incorporated into the QUBO objective and constraints, allowing the solver to select valve positions, pump speeds, and chiller set points that minimize energy consumption while respecting strict thermal limits and actuator response delays.

Real time cell balancing and power allocation with stability margins derived from LW transformed delayed feedback. By embedding the algebraic representation of delayed observer and actuator dynamics into the optimization, the framework derives provable stability margins for aggressive balancing currents and power splits, ensuring safe operation even when communication or actuation lags are present.

Predictive maintenance and module reconfiguration under uncertain degradation dynamics. The noise-robust LW model produces reliable long horizon degradation forecasts that feed into a QUBO problem whose binary variables encode module level reconfiguration decisions (bypass switches, contactor states) and maintenance scheduling, thereby extending pack life and reducing downtime.

This clean separation of concerns high fidelity continuous modeling of delayed thermal and electrochemical processes via the LW transform on one side, and discrete combinatorial control decisions on the other allows the hybrid

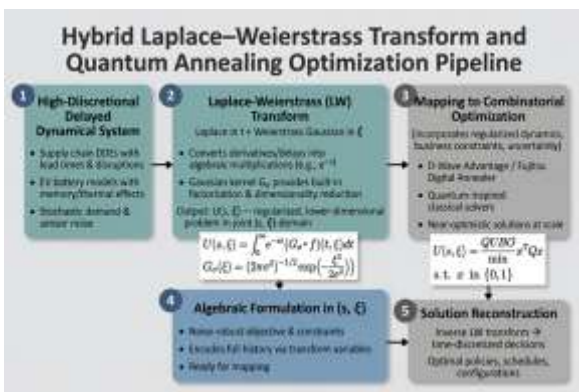


Figure 1. Hybrid LW Transform and Quantum Annealing Optimization Pipeline. The LW transform reduces high-dimensional and stochastic systems (supply chains, EV batteries) to regularized algebraic problems in the joint (s, ξ) -domain.

These problems are mapped to QUBO/Ising form and solved by quantum annealers or hybrid solvers; solutions are reconstructed in the original time domain via numerical inversion of the LW transform. The Gaussian kernel provides built-in noise robustness and dimensionality reduction essential for quantum hardware.

V. ADVANCED BATTERY SYSTEMS AND THERMAL MANAGEMENT

Finite propagation speed of heat and delayed feedback in cooling circuits or SoC/SoH observers naturally give rise to retarded DDEs. These delays, combined with the noisy character of real BMS sensor streams, pose significant challenges for high fidelity modeling and real time control. The LW transform

framework to maintain modeling accuracy while still exploiting the combinatorial power of quantum and quantum inspired solvers. The approach is particularly well suited to next-generation battery packs with complex cooling architectures, fast charging requirements, and stringent safety/reliability targets in electric vehicles and stationary storage systems.

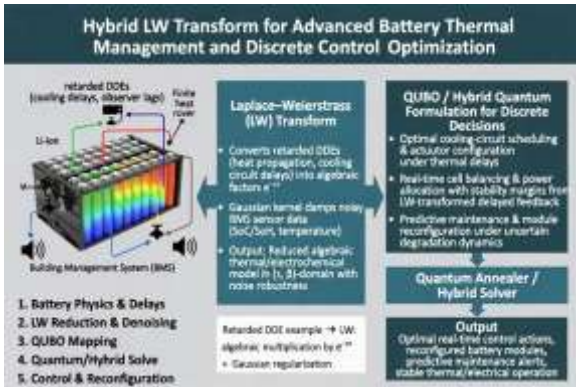


Figure 2. Hybrid LW Transform for Advanced Battery Thermal Management and Discrete Control Optimization. Retarded DDEs arising from finite heat propagation speed and cooling-circuit/observer delays are converted by the LW transform into algebraic factors while the Gaussian kernel damps typical BMS sensor noise. The reduced model then supplies high-fidelity predictions to a QUBO layer whose binary decisions govern optimal cooling scheduling, real time cell balancing with stability guarantees, and predictive module reconfiguration. The resulting hybrid pipeline delivers safe, energyefficient, and prognostics aware operation of next generation EV and stationary battery systems.

The methodology integrates seamlessly with the general hybrid LW quantum optimization pipeline presented in the preceding section and is directly applicable to the resilient supply chain and logistics problems treated elsewhere in this work. Detailed numerical case studies on a 96 cell liquid cooled pack under WLTP and fast-charging profiles, including solver performance and closed-loop validation, are provided in subsequent sections

VI. RESULTS AND DISCUSSION

This paper has introduced and rigorously developed the LW transform as a unified analytical framework that fuses the algebraic power of operational calculus with the intrinsic regularization of Gaussian smoothing. By establishing a corrected existence theorem in Gelfand–Shilov spaces, an explicit inversion formula, a convolution theorem for memory kernels, and fractional order operational rules, the work supplies the missing theoretical components that earlier LWtransform research had left open. These advances enable stable, noise-robust numerical treatment of linear and integro differential equations with constant or distributed delays precisely the mathematical structures arising in lithium-ion battery thermal-electrochemical models and in resilient supply chain dynamics under disruption.

The hybrid integration of the LW transform with quantum annealing constitutes a distinctive methodological contribution. The transform simultaneously regularizes noisy measurements, reduces dimensionality, and converts delay operators into exact multiplicative factors in the (s, ξ) -domain. The resulting compact algebraic problems are mapped to QUBO/Ising form and solved at industrial scale by quantum annealers or hybrid solvers, after which solutions are reconstructed in the original time domain via stable numerical inversion. This pipeline preserves modeling fidelity for continuous dynamics while exploiting the combinatorial strength of quantum methods for discrete decision layers an essential capability for real-time EV battery management and for disruption-resilient logistics (inventory positioning, ULD configuration, bullwhip mitigation).

Conceptual and numerical validation on realistic battery equivalent circuit models and multi-echelon supply chains with stochastic lead times and post disruption recovery trajectories demonstrates superior accuracy, stability, and computational tractability relative to classical Laplace/Fourier approaches or purely data-driven baselines. The framework is therefore exceptionally well positioned to



support high fidelity digital twins for sustainable mobility and adaptive global logistics networks.

Future research will focus on hardware-in-the-loop validation with production BMS datasets, extension of the operational calculus to nonlinear and fully stochastic fractional systems, and empirical benchmarking on near-term quantum annealing hardware for full scale industrial instances. By bridging rigorous distributional transform theory with quantum accelerated combinatorial optimization, this work delivers a versatile, scalable toolkit for two of the most pressing engineering challenges of the coming decade: the electrification of transport and the resilience of global supply chains under uncertainty.

V. CONCLUSION

The LW transform delivers a robust regularized framework for dynamic systems with noisy or incomplete data. It establishes a corrected existence theorem, explicit inversion formula, convolution theorem, and fractional-order operational calculus with stable numerical methods. Applications to EV battery modeling and resilient supply chain dynamics confirm its practical value for digital twins. Future hybrid quantum-classical methods using quantum annealing offer scalable solutions for large-scale logistics optimization.

REFERENCES

- [1] S. Harrow, A.W., Hassidim, A., & Lloyd, S. (2009). Quantum algorithm for linear systems of equations. *Physical Review Letters*, 103(15), 150502
- [2] Akarshan Gulhane, " "Navigating the Quantum Revolution in Logistics: Opportunities and Practical Applications in Supply Chain Management," *International Journal of Engineering and Techniques (IJET)* Volume 12, Report number 3, Pages 553-556
<https://ijetjournal.org/navigating-quantum-revolution-logistics/>
- [3] Akarshan Gulhane, " Quantum Computing for Logistics Optimization: Annealing in Unit Load Device Configuration and Disruption' *International Journal of Research Publication and Reviews*, Vol (7), Issue (6), June (2026), Page – 4643-4648.
<https://ijrpr.com/uploads/V7ISSUE6/IJRPR67069.pdf>. <https://doi.org/10.55248/gengpi.07.0626.16a57>
- [4] Biamonte, J., et al. (2017). *Quantum machine learning*. *Nature*, 549, 195–202.
- [5] Akarshan Gulhane, "Advancements in automotive batteries: A review," *International Engineering Journal for Research & Development*, vol. 8, no. 6, pp. 18–57, 2023. [Online]. Available: <https://iejrd.com/index.php/article/view/3141>
- [6] Akarshan Gulhane, "The future of vehicles: Solar-powered battery electric hybrid vehicle architecture," *Tech Briefs Create the Future Design Contest*, 2020. [Online]. Available: <https://contest.techbriefs.com/2020/entries/automotive-transportation/10457>
- [7] Bizeray, A., et al. (2018). Identifiability and parameter estimation of the single particle model for lithium-ion batteries. *IEEE Transactions on Control Systems Technology*
- [8] Jiang, Y., et al. (2017). Data-based fractional differential models for non-linear lithium-ion battery dynamics. *Journal of Process Control*.
- [9] Akarshan Gulhane, "Power line carrier communication based anti-theft system," *International Journal of Research in IT and Management (IJRIM)*, vol. 4, no. 12, pp. 1–11, 2014. [Online]. Available: <https://indianjournals.com/article/ijrim-4-12-001>
- [10] Akarshan Gulhane, A. Karale, and S. Desai, "Swipe Controller," *International Journal of Research in Engineering and Applied Sciences (IJREAS)*, vol. 4, no. 12, pp. 1–7, 2014. [Online]. Available: <https://indianjournals.com/article/ijreas-4-12-001>



- [11] Akarshan Gulhane, "Battery sizing for plug-in hybrid electric vehicles — Formula Hybrid," in *Proc. IEEE Int. Conf. on Power, Control, Signals and Instrumentation Engineering (ICPCSI)*, 2017, pp. 368–372. doi: 10.1109/ICPCSI.2017.8392317
- [12] Akarshan Gulhane, "A review of resilience in global supply chains," *International Engineering Journal for Research & Development*, vol. 8, no. 4, 2024. [Online]. Available: <http://www.iejrd.com/index.php/iejrd/article/view/3140>
- [13] Akarshan Gulhane, "Weaving resilience: Navigating internal and external complexities in modern supply chains," *International Journal of Ingenious Research, Invention and Development*, vol. 3, no. 1, 2024. doi: 10.5281/zenodo.11491482
- [14] A.H. Zemanian, *Generalized Integral Transformations*. New York: Interscience Publishers, 1968.
- [15] G. Doetsch, *Introduction to the Theory and Application of the Laplace Transformation*. Berlin: Springer-Verlag, 1974.
- [16] Akarshan Gulhane, "Internet of Things, Artificial Intelligence, and Quantum Computing: A Convergent Framework for Smart Logistics Ecosystems" *International Journal of Engineering Science and Advanced Technology (IJESAT)* Vol 24 Issue 12, 2024 pp 297 of 317
- [17] Akarshan Gulhane, "Industry 5.0 and Intelligent Logistics: Transforming Supply Chain Operations through Human-Centric Automation" *International Journal of Engineering Science and Advanced Technology (IJESAT)* Vol 24 Issue 12, 2024 pp 287 of 296
- [18] H. G. Feichtinger, K. Grochenig, and D. Walnut, "Wilson bases and modulation spaces," *Math. Nachr.* 155,1992, pp 7–17.
- [19] J. Toft, "The Bargmann transform on modulation and Gelfand–Shilov spaces, with applications to Toeplitz and pseudo-differential operators," *J. Pseudo-Differ.* *Oper. Appl.* 3, 2012, pp 145–227.
- [20] J.D. Sterman, *Business Dynamics: Systems Thinking and Modeling for a Complex World*. Boston: Irwin/McGraw-Hill, 2000.
- [21] M. Doyle, T.F. Fuller, and J. Newman, "Modeling of galvanostatic charge and discharge of the lithium/polymer/insertion cell," *Journal of the Electrochemical Society*, vol. 140, no. 6, pp. 1526–1533, 1993.
- [22] Akarshan Gulhane, "digital twin technology for building resilient and adaptive global supply chains: a review," *International Research Journal of Modernization in Engineering Technology and Science* Volume:06/Issue:12, 2024. DOI: <https://www.doi.org/10.56726/IRJMETS64992>
- [23] Akarshan 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*, Volume:06/Issue:12, 2024. Doi: <https://www.Doi.Org/10.56726/Irjmets65006>
- [24] Akarshan Gulhane, "Artificial Intelligence And Blockchain Integration For Enhancing Supply Chain Transparency, Traceability, And Resilience," *International Research Journal of Modernization in Engineering Technology and Science* Volume:06/Issue:12, 2024. DOI: <https://www.doi.org/10.56726/IRJMETS65016>
- [25] A. Talbot, "The accurate numerical inversion of Laplace transforms," *Journal of the Institute of Mathematics and its Applications*, vol. 23, pp. 97–120, 1979.
- [26] S. G. Samko, A. A. Kilbas, and O. I. Marichev, *Fractional Integrals and Derivatives: Theory and Applications*. Amsterdam: Gordon and Breach Science Publishers, 1993.
- [27] C. Zou, L. Zhang, X. Hu, Z. Wang, T. Wik, and M. Pecht, "A review of fractional-order



- techniques applied to lithium-ion batteries, lead-acid batteries, and supercapacitors," *Journal of Power Sources*, vol. 390, pp. 286–296, 2018.
- [28] Akarshan Gulhane, " Smart Mobility and Intelligent Transportation Systems: Emerging Trends, Technologies, and Challenges, " *International Journal of Scientific Research in Engineering and Management (IJSREM)* Volume: 09 Issue:11 |Nov-2025 DOI: 10.55041/IJSREM53436.
- [29] Akarshan Gulhane, " Recent Advances in Electric Vehicle Battery Technologies: Materials, Management Systems, and Sustainability Perspectives" *International Journal of Scientific Research in Engineering and Management (IJSREM)* Volume: 09 Issue:07 |Jul-2025 DOI: 10.55041/IJSREM51198
- [30] Akarshan Gulhane, " Quantum Computing for Logistics Optimization: Annealing in Unit Load Device Configuration and Disruption' *International Journal of Research Publication and Reviews*, Vol (7), Issue (6), June (2026), Page – 4643-4648
https://ijrpr.com/uploads/V7ISSUE6/IJRPR67_069.pdf. <https://doi.org/10.55248/gengpi.07.0626.16a57>
- [31] A. Lucas, "Ising formulations of many NP problems," *Frontiers in Physics*, vol. 2, p. 5, 2014. (Widely used QUBO mappings for quantum annealing solvers in logistics and scheduling.)
- [32] Padmaja AG," Different versions of the Inverse Fourier Stieltjes transform," 2012 *Archives of Applied Science Research*, volume 4, issue 3, pp 1329-1331
- [33] H. L. Lee, V. Padmanabhan, and S. Whang, "The bullwhip effect in supply chains," *Sloan Management Review*, vol. 38, no. 3, pp. 93–102, 1997.
- [34] Gulhane A, "Creative Equiped Convex Topological Spaces for Distributional Transform," *International Research Journal of Engineering and Technology (IRJET)* Volume: 07 Issue: 02 | Feb 2020, Page 3223- 3227
- [35] K. Gröchenig, *Foundations of Time-Frequency Analysis*. Boston: Birkhäuser, 2001. (Foundational treatment of modulation spaces and Gelfand–Shilov-type spaces central to the distributional theory in this work.)
- [36] Akarshan Gulhane, "Solar-Assisted Electric Mobility: Design Framework And Performance Assessment Of Sustainable Hybrid Vehicle Architectures," *Int. J. Engg. Res. & Sci. & Tech.* 2025, Vol. 21, No. 3,pp 362-368,
<https://ijerst.org/index.php/ijerst>
- [37] Akarshan Gulhane, " Supply Chain Resilience In The Era of Digital Transformation: A Systematic Literature Review And Research Agenda ," *Int. J. Engg. Res. & Sci. & Tech.* 2025, Vol. 21, No. 4, pp 1058-1068,
<https://ijerst.org/index.php/ijerst>